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ENGINEERING

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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LITERATURE.

A Treatise on Gyrostatics and Rotational Motion. By ANDREW GRAY, F.R.S., Professor of Natural Philosophy in the University of Glasgow. London: Macmillan and Co., Limited. [Price 42s. net.]

THIS is a book that has long been wanted. Much of the literature connected with the discussion of gyrostatic action and rotational motion is scattered and of very varied value for, attracted by the many-sided interest centred in the paradoxical properties with which rotating bodies are seemingly endowed, numerous writers have explained the theory of particular phenomena or perhaps have suggested applications that have not always proved as successful in practice as the ingenious devisers fondly anticipated. A complete and comprehensive analysis that welded the many details into compactness, supplying a common connecting thread that permitted a discerning view of the whole was wanting, and if we turn from chapter to chapter in these 500 pages the reason is not far to seek. A satisfactory treatment needed the hand of a master whom long study had familiarised with the subject, one who, as the author, had been trained under Lord Kelvin, profited by the teaching of Greenhill, and who possessed both mathematical and mechanical tastes. Professor Gray's qualifications for the task he has undertaken are well known, and we may congratulate ourselves that he has found the leisure to carry his work to full fruition. This treatise will enhance the already high reputation the author enjoys as a competent exponent of intricate rotational problems, while the work itself is of remarkable interest and will be of the greatest practical assistance to serious students.

It is not easy, perhaps impossible, to popularise rigid dynamics, while preserving strict accuracy, and the author has not attempted to overcome the difficulty to any great extent. He addresses those rather who have found the treatment of gyrostatic problems in the lecture room and in the ordinary text-book too restricted, too much confined to special cases, that have become classical or hackneyed. Professor Gray's experience has shown him that when the treatment has been conducted on more comprehensive lines, it is too often limited to applications of Euler's or Lagrange's equations, which "by providing a walled-in path along which the mind can travel, withdraw its attention from the incidents, often exceedingly instructive, which attend its progress." The aim here is to stimulate the curiosity of the student, clear the difficulties to some extent from his path, provide a mental discipline, and to ensure that the matter is interesting and suggestive. The method is to refer generally each gyrostatic problem directly to first principles, and this object is sought to be effected by the analytical and numerical discussion of problems arising from actual experiments made with the special apparatus, which is to be found in the laboratories and workshops of those physical institutes where real dynamics are earnestly and properly taught.

We have travelled far since the problem of the Precession of the Equinoxes formed the favourite illustration of gyroscopic action. Mechanism has become more delicate as more powerful, and the consequences of rotational motion are easily detected in the swift-running machinery of modern plant. Gyroscopic action can operate so weirdly, that when inexplicable misadventures have occurred, it has been invoked to explain the cause, generally on quite insufficient grounds. On the other hand, we have enlisted this force as a powerful mechanical agent and when properly applied have welcomed its services, though occasionally some have found that the confidently expected result has not been realised. The proposal to construct on passenger steamers a cabin that would not be effected by the motions of the vessel is a well-remembered and instructive case. The suggestion was to control the oscillation of a saloon suspended from a fore-and-aft axis, by means of a gyroscope with a vertical axis of spin. The freedom of precession about an axis athwart the ship was not provided for in the general arrangement, and consequently the rolling effect was not reduced. The proper method, or at least a more satisfactory one, as no doubt many students have been required to prove since, would have been to have suspended the cabin on fore-and-aft trunnions, and mounted the gyrostat within the cabin on trunnions placed athwart the ship. Schlick could profit by the mistakes of his predecessors, and his experiment has proved successful. He aimed rather at the steadying of the ship than to make a portion of it independent of the general motion. In his plan, a gyroscope is fixed so that when the ship is on an even keel and the gyroscope is in equilibrium, the axis of the flywheel is vertical. The wheel is pivoted on a frame whose motions are damped by a brake pulley having a graded amount of friction. The action of such a gyroscope is to endow a small ship with the period of a large one, for the introduction of the rotating flywheel results in a large vertical increase of moment of inertia. The effect of the brake pulley tends to prevent the ship from rolling; it damps out the free oscillations of the system.

The steering of the dreaded torpedo on its fatal mission is far simpler. In the absence of a couple producing precession, the axis of rotation preserves a permanent direction. It is therefore only necessary to insert a fast-spinning gyrostat with its axis coincident with that of the torpedo. Should the torpedo swerve in its path a relative shift is introduced between the gyrostat and the torpedo axis, and this shift can easily be made to move a rudder at the stern, that brings the torpedo back into its course. The gyrostat both detects the swerve and operates the mechanism necessary to correct it. If we require another and more beneficial application of rotational forces it is found in the gyro-compass, that has practically displaced the magnet which has so long proved itself indispensable in navigation. In this direction-pointer, ingenuity has secured an instrument that remains unaffected by the iron of the ship, by the tossing of the vessel or by its position on the Earth's surface. The monorail-car further illustrates another direction in which the gyrostat is shown to be capable of doing work. This device, or some further development of the mechanism, may some day be turned to practical account, although the mono-rail is far from possessing all the advantages claimed for it.

On the other hand, the effects of gyrostatic action, as inevitable as those of gravity, that in some respects they seem to contradict, may bring drawbacks that may not be overlooked without inconvenience. The action of a flywheel in a motor car may force itself on the attention of the driver by tending to produce skidding of the wheels on the ground, or in affecting the steering power of the car. In the aeroplane, the rotor of the engine and the propeller together form a compound gyrostat of considerable power, and the aviator should know what to expect and how to meet any sudden emergency that may arise. All fast-speed turbines and rotary engines need more study than the average engineer, or those in charge of the finished mechanism, have given to the subject. It has been remarked that many engineers, who are familiar with the laws of motion of translation, are ignorant of angular motion, notwithstanding that the analogies between the two sets of laws are perfectly simple. Professor Gray's treatise is well adapted to correct this inequality, by supplying a complete survey of the whole subject, in which is made a continual appeal to first principles.

To give within a reasonable space an adequate summary of the contents is impossible. They include the action of forces of cosmical importance on the one hand, and of the infinitely minute on the other. One would like, however, to indicate to those who take a limited view of the subject, and have followed it no further than in connection with practical mechanics, that gyrostatic action has been utilised to explain more recondite matters than the spinning of a top or the behaviour of rotating machinery. It is one of the author's distinct successes to have shown that the motion of an electron in a magnetic field is strictly analogous to that of a rigid pendulum in the bob of which is a flywheel with its axis in line with the suspension rod of the pendulum. Professor Gray has further sought to deduce an explanation of the Zeeman effect, by gyrostatic illustration, but apparently difficulties arise on account of the complex of spectral lines. Another example of unexpected subtlety in this far-reaching subject is Lord Kelvin's attempt to frame a kinetic theory of elasticity, in which the rigidity of bodies would depend on motions of parts of the bodies hidden in the body itself, as the flywheel of a gyrostat is hidden from sight by the case enclosing it. One might quote numerous other instances, not only in physics, but in engineering, where instructive analogies occur and then leave the subject far from exhausted. In a final chapter, the author collects a number of problems that indicate the wide ramifications of the subject, and he further promises to supplement this list by a second volume, dealing with the application of gyrostatic devices to naval and military affairs, as well as to practical engineering. The abnormal conditions created by the war have prevented the fullness of discussion that was desirable, but with the removal of necessary restrictions a very illuminating volume should result.

The form of mathematical analysis adopted will not recommend the book to beginners. It presupposes very considerable familiarity with mathematical methods and symbols. The wider one's acquaintance with modern analysis, the greater the benefit to be derived. Of quite equal importance, is the power to translate formulæ into intelligible expression, or to be able to interpret the conclusions symbolically expressed. To those who have not this power, and can follow the processes simply as algebraical deductions, step by step, much of the work is written practically in an unknown tongue. This does not imply any censure on the author, and the remedy is for the pupil to acquire greater mastery of the language. Professor Gray says that in Glasgow the subject is traditional, and possibly he enjoys the advantage of addressing those to whom "the perception of the action of more or less complicated gyrostatic or other dynamical devices, becomes in time and with the continued exercise of thought, intuitive, when the processes are fundamental and interpretative." Many, however will find that a very close attention to the subject is needed, but the reward to be expected is a clearer grasp of general principles, and a more penetrative insight into the causes of mechanical action.

The Applications of Electrolysis in Chemical Industry. By ARTHUR J. HALE, B.Sc., F.I.C., Demonstrator and Lecturer in Chemistry, The City and Guilds of London Technical College, Finsbury. London: Longmans, Green and Co. [Price 7s. 6d. net, bound.]

THE stimulated interest now taken in matters electrochemical in this country is indicated by the recent publications of new books on the subject. Detailed technical information on novel processes is hardly likely to be published at present. One might expect then that new books would bring fuller information on established processes; but one can hardly say that they do. Mr. Hale deals with "Applications of Electrolysis in Chemical Industry." He excludes not only electrochemical analysis, but also electroplating, an important branch of the industry, which has been extended in recent years; the fact might have been stated by Mr. Hale. The eight chapters of his volume are on Methods of Generating the Current; the Electrolytic Refining of Metals; the Electrolytic Winning of Metals; Electrolytic Production of Hydrogen and Oxygen; Electrolysis of Alkali Chlorides, Chlorine and Caustic Soda, Hypochlorites, Chlorates and Perchlorates (two chapters); Production of Inorganic; and Production of Organic Compounds. The general theory and general considerations are limited to an Introduction of 15 pages, which is too much of the nature of an abstract. The student is told that the chemical equivalent is approximately 96,500 coulombs; Joule's law (unexplained) is written $H = I^2 rt$; later on we read: "The quantity of electricity which passes a certain point in a conductor in unit time is the current, and this is analogous to the flow of water"; Ohm's law is expressed $I = E/R$, but there are no clear definitions of the ampere and the coulomb. "Electrical osmosis is the term applied to the transport of the constituents of an electrolyte through a diaphragm when one is used to separate anode from kathode" Immediately below that paragraph

follows the heading "Cataphoresis or the Transport of Colloids"; the dehydration of peat is mentioned (there is no name or reference), and some positive and negative colloids are enumerated; but it is not explained why the water is forced through the kathode. This introduction is altogether inadequate. The first chapter (14 pages) on current generation, deals in six pages with primary and secondary cells, and passes on to thermopiles and to the dynamo and power (three more pages). The one page on thermopiles mentions two names, Clamont and Gulcher; it is said that the Gulcher type is the only one employed, but it is not made clear of what elements Gülcher builds up his pile. The whole chapter, we see from the preface, was added at the suggestion of Sir Edward Thorpe, the editor of the series of Monographs on Industrial Chemistry, to which the volume belongs. Mr. Hale would have done well, we think, to disregard that suggestion, and to concentrate more on his own subject. The whole book consists of only 148 pages.

Mr. Hale writes concisely and to the point. A very recommendable feature of his compilation is that he has taken pains to ascertain where the processes are actually worked, and that he keeps technical considerations well to the front. There is a good deal more in the book than appears from the two indexes; that is against the book by comparison with more comprehensive and complete and better-indexed books with which this publication might well compete in other respects. Insufficient attention has, moreover, been paid to the literature of recent years; the chapter on organic compounds contains only one reference to 1913 and none to later years, the detinning problem is very briefly dealt with, there are four lines on electrochemical sewage disposal, and the electrochemical separation of oil from water is not mentioned. The book certainly has its good points; but a larger volume would have been more satisfactory and hardly more difficult to compile. The author may, however, have been restricted as to space.

BOOKS RECEIVED.

How to Deal with Different Kinds of Fires. By SIDNEY G. GAMBLE, F.S.I., Assoc.M.Inst.C.E. London: The Offices of the British Fire Prevention Committee. 8, Waterloo-place. [Price 3s. 6d., post free 3s. 8d.]

Juvenile Employment, During the War and After; the Report of an Inquiry. With a Foreword by the Right Hon. C. ADDISON, M.D., M.P. London: Ministry of Reconstruction, 2, Queen Anne's Gate Buildings, S.W. 1.

American Engineers Behind the Battle Line in France. By ROBERT K. TOMLIN, Junr., London: Hill Publishing Company, Limited. [Price 10s. net.]

Electricity and Magnetism for Engineers. Part I. *Electric and Magnetic Circuits.* By HAROLD PENDER, Ph.D. London: Hill Publishing Company, Limited. [Price 15s. net.]

Reconstruction Problems. No. 6. *Raw Materials and Employment.* No. 7. *Guide to Work and Benefits for Soldiers and Civil War Workers.* No. 10. *Labour Conditions and Adult Education.* London: Ministry of Reconstruction. [Price 2d. each.]

Catalysis in Industrial Chemistry. By G. G. HENDERSON, D.Sc., LL.D., F.R.S. London: Longmans, Green and Co. [Price 9s. net.]

United States Bureau of Mines. Technical Papers. No. 154. *Suggestions for Improved Methods of Mining Coal on Indian Lands in Oklahoma.* By J. J. RUTLEDGE and DANIEL HARRINGTON. No. 139. *Low-Rate Combustion in Fuel Beds of Hand-Fired Furnaces.* By HENRY KREISINGER, C. E. AUGUSTINE and S. H. KATZ. No. 186. *Methods for Routine Work in the Explosives Physical Laboratory in the Bureau of Mines.* By S. P. HOWELL and J. E. TIFFANY. No. 192. *Production of Explosives in the United States during the Calendar Year, 1917.* By ALBERT H. FAY. No. 205. *Saving Coal in Boiler Plants.* By HENRY KREISINGER. No. 206. *Coke-Oven Accidents in the United States during the Calendar Year 1917.* By ALBERT H. FAY. Washington: Government Printing Office.

United States Bureau of Mines. Chart of Properties of Mine Gases: Physiological Effect of Different Gases on Man. By G. A. BURRELL. Washington: Government Printing Office.

United States Bureau of Labour Statistics. Whole Number 236. *Effect of the Air Hammer on the Hands of Stone Cutters.*

A System of Physical Chemistry. By WILLIAM C. MCLEWIS, M.A.(R.U.I.), D.Sc.(Liv.). Second Edition. In three volumes. Vol. I. *Kinetic Energy.* Vol. II. *Thermodynamics.* London: Longmans, Green and Co. [Price 15s. each volume.]

Manual of Electrical Undertakings and Directory of Officials, 1918–19. Compiled under the direction of EMILE GARCKE, M.I.E.E., F.S.S. London: Electrical Press, Limited. [Price 22s. 6d. net.]

The Cycling Manual. Third Edition. London: Temple Press, Limited. [Price 1s. net.]

THE MEASUREMENT OF FLUID VELOCITY AND PRESSURE.

By J. R. PANNELL, A.M.I.M.E., F.R.Ae.S.

(*Concluded from page* 366.)

MANOMETERS.

Manometers and pressure gauges may be divided into two main classes, (1) those which depend on the action of gravity and (2) those which do not depend on gravity.

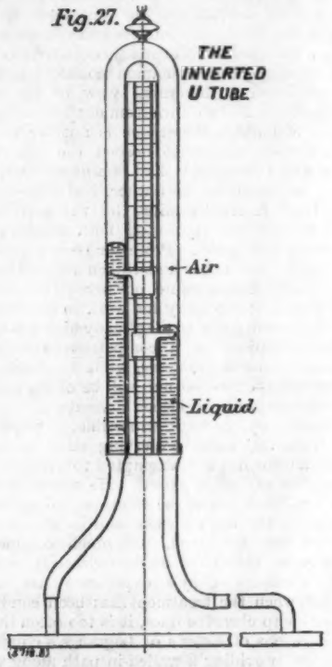
Of the first class the most common type is the U-tube, in which the pressure is measured as a head of liquid. If an air pressure of such a magnitude

FIG. 26. THE FORTIN BAROMETER.

that its value as a head of water (or mercury) can be conveniently measured to the required accuracy a plain U-tube will suffice.

The Mercury Barometer is an instrument of the U-tube type which, when there is no wind, measures the static pressure of the atmosphere. In this case the pressure at the surface of the mercury in one limb of the tube is reduced practically to zero by sealing up that limb and exhausting the space in it above the mercury as completely as possible. The difference in level of the surfaces in the two limbs (which in London normally varies from about 740 mm. to 790 mm.) constitutes a measure of the pressure. Standard barometers usually consist essentially of a vertical glass tube sealed at the upper end, and a cistern containing mercury in which the lower end of the vertical tube is immersed. In filling the barometer the vertical tube is inverted, filled with mercury and, precautions having been taken to ensure the expulsion of all air and water vapour, turned again into its normal position with its lower end below the level of the mercury in the cistern. The mercury will stand in the tube at such a height above the lower surface of the mercury as to balance the atmospheric pressure. Fig. 26 shows the Fortin barometer which has been much used as a standard instrument and in which the cistern has glass walls and a flexible bottom of leather. Before taking an observation the surface of the mercury in the cistern is brought just into

Fig.27.



contact with a fixed point on the instrument in order that the whole change of level may be measured at the mercury surface in the tube. This adjustment, which can be carried out with considerable accuracy by observing the reflection of the point in the bright surface of the mercury, is effected by turning a screw which deflects the leather base of the cistern. In the provision of this adjustment the Fortin instrument differs from many modern barometers in which the mercury cistern is rigid throughout, the motion of the lower mercury surface being allowed for by contracting the scale on which the position of the upper surface is read. A vernier which is provided at the upper level of the mercury can be read to one-tenth mm. giving an accuracy of nearly 1/100th of 1 per cent. In order to reduce barometer readings to a standard basis a temperature correction is applied to allow for expansion of the scale and the mercury column; the readings are also reduced according to a standard method to the equivalent value at sea level.

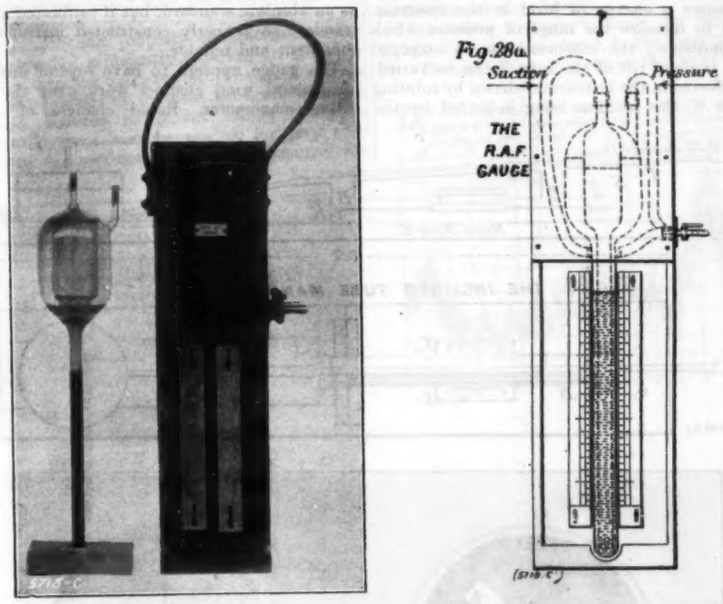
Aneroid barometers are also extensively used, the principle upon which they operate being entirely different from that of the type just described. Their indications depend upon the deflection of a diaphragm forming one wall of an airtight box from which the air has been exhausted. The motion of the diaphragm is highly magnified and transmitted by a system of levers to a needle moving over a graduated dial.

The U-tube type of instrument will also serve for measurement of a pressure due to water and a column of mercury (in water) may be employed if the pressure difference to be measured gives a suitable head for the accuracy required. It must be borne in mind that under the latter circumstances the effective density of the mercury is 12·56 instead of 13·56 as for mercury in air.

For water pressure differences which are too small to be measured on a mercury U-tube a con-

venient arrangement is that shown in Fig. 27. The U-tube is here inverted, the upper portion containing air, and the pressure difference is given by the difference of level of the water in the limbs of the U-tube. If measurements of the velocity of a free stream of liquid were being made by means of pitot and static tubes and the tap at the top of the U-tube were left open, the height of fluid on the static pressure side would coincide with the mean level of the free surface of the stream and the gauge be difficult to read. This difficulty may be overcome by reducing the air pressure in the upper part of the tube and closing the tap when the surfaces have been raised to a convenient height for observation. On the other hand if a pressure difference in a pipe through which fluid is being transmitted under pressure, is to be measured, it might be necessary to increase the air pressure in the U-tube to prevent the liquid in the high pressure limb flowing over at the top of the gauge.

Another modification may be made for still lower pressures by filling the space above the water with oil when, since the densities of the two fluids are now nearly equal, a large displacement can be obtained for a small pressure difference. The latter arrangements has not, however, been found satisfactory in use; the zero positions of the surfaces of separation are liable to change after a pressure difference has been applied, an error which is often increased by globules of oil adhering to the wall of the tube and remaining in the water.



FIGS. 28 AND 28A. PORTABLE TWO-FLUID GAUGE.

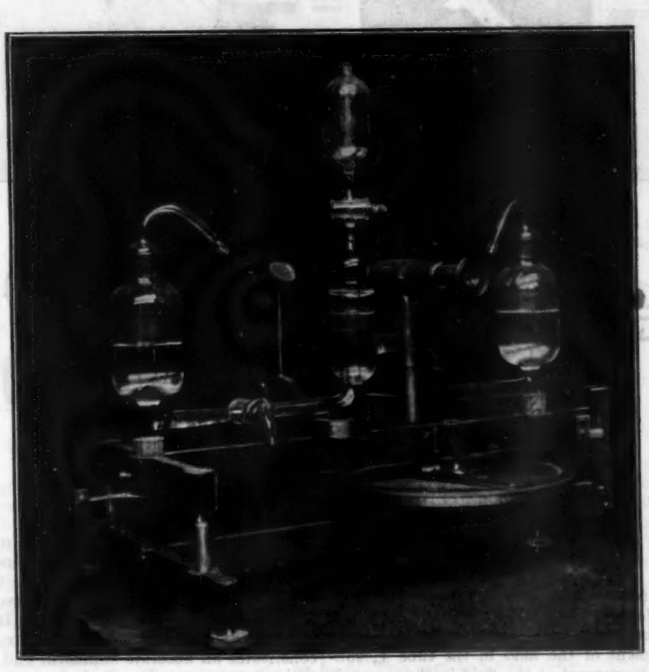


FIG. 29. N.P.L. TILTING MANOMETER.

A portable two-fluid gauge which was fairly satisfactory for small air pressures was that designed at the Royal Aircraft Establishment and shown in Figs. 28 and 28A. The guage is essentially a U-tube, the limbs of which are arranged concentrically in order to reduce error due to tilting. The choice of the liquids is determined by several considerations. First, the separation surface of the two fluids must be well defined and remain of the same shape whether rising or falling; it is also important that after displacement no bubbles of liquid should remain adhering to the wall of the tube. Second, the ratio of the densities of the two liquids must be such that a sufficiently large movement is obtained for the head to be observed with the necessary accuracy. One pair of liquids which was used with this gauge was methyl-alcohol and petrol, the former being stained; they were found to be fairly satisfactory except that they were rather volatile, and appreciably soluble in each other at summer temperature. Another combination, the fluids of which are much less volatile, is amyl-ether and water, the latter being stained with a small quantity of bichromate solution to improve visibility.

In a manometer designed by Threlfal* an attempt was made to obtain the necessary accuracy in measuring small pressures due to the flow of gas in a gas producer main, by using a plain water U-tube and taking measurements of the position of the two surfaces to a high degree of accuracy. This was effected by approaching two needle points to the surfaces, and under careful illumination noting the position at which they touched the water. It is stated that the gauge is sensitive to a head of 0·01 mm. of water, but it has now been superseded by the more convenient tilting manometer which has been developed on the lines of that used by Professor A. P. Chattock in 1900.†

The N.P.L. Tilting Manometer,‡ is now in general use on the wind channels at the National Physical Laboratory. This gauge may be used as an absolute standard since the pressure difference can be calculated from the reading of the hand wheel, the dimensions of the gauge and the density of the fluid employed in the end cups.

The essential feature of the instrument, of which the two liquid type is shown in Fig. 29, is that by means of the tilting device, motion of the fluid is reduced to a negligible amount and surface tension and capillarity troubles are avoided. The gauge consists of a U-tube of which the two vertical limbs are cylindrical vessels 2 in. in diameter. The horizontal limb is cut and connected to a third cylindrical vessel, the right portion of the limb being bent upwards through a right angle and fixed accurately in the centre of this vessel; the left portion is connected to the vessel near its lower end. The lower parts of these three vessels and the horizontal tubes are filled with a solution of distilled water and common salt of a density of 1·07, while the upper part of the central vessel, to a point below the top of the central tube, contains castor oil. The level of the gauge is adjusted so that the salt water-oil separation surface inside the small tube is at its upper extremity and curved upwards in such a manner as to be readily seen in the microscope. The object of this device is to enable the observer to detect, by the displacement of this surface of separation, any tendency of the fluid to flow from one end cup to the other. There are three cone joints to facilitate cleaning and a tap in the horizontal limb renders the gauge portable. The glass work is supported on a metal frame made in two parts the upper resting on three points in the lower. Two of these three points are fixed; the third can be raised or lowered by rotating the handwheel, and the upper part which carries the U-tube, tilted to the necessary angle. In observing a steady pressure difference the accuracy is limited by the precision with which the position of the separation surface can be adjusted.

The method of using the gauge is as follows: The microscope is focussed on the separation surface and the level of the gauge is adjusted till the surface is in the zero position. The reading of the hand wheel having been observed and the tap closed, the pressure difference is applied and the hand wheel set approximately to the reading. If the tap is now opened slightly it is usually possible to adjust the hand wheel sufficiently rapidly to prevent any

* Proc. Inst. Mech. Eng., 1904, page 271.
† *Phil. Mag.*, 1901.
‡ Experiments by the present writer with this gauge were described in ENGINEERING, Sept. 12, 1913, p. 343.

considerable excursion of the bubble, which is undesirable as being liable to cause change of zero or in extreme cases to rupture the surface. The tap having been fully opened the hand wheel is set so that the mean position of the bubble coincides with the zero position; the difference of the two readings multiplied by the gauge constant gives the pressure head. In the standard gauges at the National Physical Laboratory the centres of the end cups are 13 in. apart, the fulcrum about which the gauge tilts is 10 in. from the adjustable point, and the screw of the hand wheel has 20 threads per inch. The head of the fluid per revolution of the hand wheel is therefore

$$\frac{13}{10} \times \frac{1}{20} = 0.0650 \text{ in.}$$

or as the specific gravity of the salt and water solution is 1·07 the head of *water* per revolution of the hand wheel = 0·0695 in.

The gauge is easily sensitive to a movement of 1/500th part of a revolution of the wheel which corresponds to a pressure difference of 0·00014-in. of water or 0·000005 lb. per square inch. This head would be equivalent to about 1 per cent. on the velocity of a current of air at 5 ft./sec. as measured by the pressure difference in a pitot and static tube anemometer head. For measurement of speed in an air channel the accuracy is usually limited by the fluctuations of pressure, and the precision of the guage is more than sufficient.

A word as to the use of this gauge when the damping is very heavy may be useful. The plan which observers often adopt is to set the wheel at an approximately correct value and wait until an obvious movement of the bubble indicates in which direction the wheel reading should be amended. The wheel is moved say 20 divisions, and the process repeated. The author's experience with this gauge suggests that a method which is quicker (and probably more accurate) is to watch the bubble very closely and oppose the slightest motion by an appropriate movement of the wheel. When a balance has been obtained the wheel reading is observed, and the process repeated until the mean result is obtained to the desired degree of accuracy. Observations can be made by this means with an accuracy which appears impossible on a preliminary observation of a gauge when connected to heavily damped apparatus, such as the N.P.L. yaw-head. It is of the utmost importance that the velocity of the air current shall be constant for accurate experiments of this nature.

Inclined tube manometers are in use on the wind channels at Gottingen and at Washington. A convenient form of this type of gauge is the "Krell" manometer, shown diagrammatically in Fig. 30. It consists of a reservoir R, containing coloured alcohol and connected by indiarubber tubing to an inclined glass tube T. This tube is firmly attached to the frame B, which is supported by the knife edge K, and the screw S, adjustment of the zero reading being effected by rotation of the screw S, which causes a change of level in the reservoir. In order to increase the range of pressure which can be measured the manometer is so arranged that the angle of tilt of the tube T can be varied. This is effected in the instrument shown by rotating the screw S, the position being indicated by the spirit levels L_1 and L_2 which are attached to the frame and set at known angles to the tube T.

If there are no errors due to surface tension at the fluid surfaces the amount of a pressure difference applied to the gauge can be calculated by observing the displacement of the fluid in the tube T, subtracting the movement of the fluid in the reservoir R (this can be calculated if the cross sectional areas of the reservoir and tube are known), and multiplying by the sine of the angle of inclination of the tube T. The pressure is thus obtained as a head of the fluid used in the manometer and a knowledge of the density of the fluid is necessary in order to calculate the force per unit area.

Experiments with this manometer have been carried out at the Massachusetts Institute of Technology by Commander J. C. Hunsaker,* the gauge used having an inclined tube whose diameter was 0.22-in. and a reservoir with a cross sectional area about 400 times as great.

It was found necessary to use the best quality glass for the tube, which was cleaned with strong sulphuric acid and potassium bichromate. The tube was inclined at 3 deg. or 6 deg. to the horizontal, depending on the pressure to be measured. It was finally concluded that the gauge could not be used as an absolute standard, but if calibrated against a standard, a properly constructed instrument was consistent and reliable.

The gauge appears to have several advantages for general wind channel work over the N.P.L. tilting manometer. Rapid changes of pressure (such as would occur on the failure of the electric supply of the motor driving the airscrew) would not put the gauge out of action, the mean of fluctuations can be readily observed, and the instrument is cheaper to construct. It is, however, always advisable to have one instrument which constitutes an absolute standard, and as such, the tilting manometer described above is admirable.

A form of this manometer employed in Germany has a curved tube, and when graduated to read wind speed direct gives a practically uniform scale.

We may now turn to the second class of manometer which does not depend on the action of gravity.

The Bourdon Pressure Gauge.—This gauge is used almost exclusively for measurement of steam pressures and over a wide range of purposes where it is desired to measure pressures of considerable magnitude with moderate accuracy. The action of the gauge will be readily understood on reference to Fig. 31, which shows the closed tube of oval

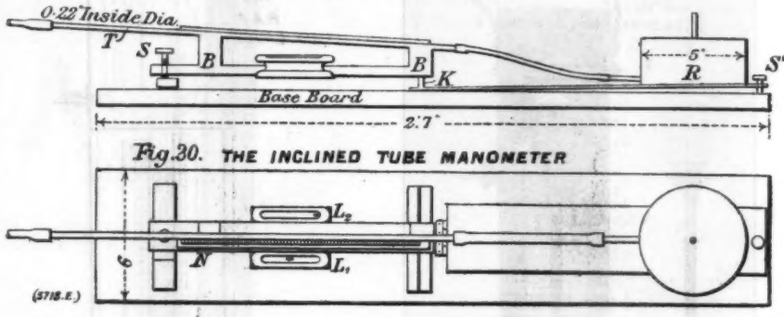


Fig. 30. THE INCLINED TUBE MANOMETER

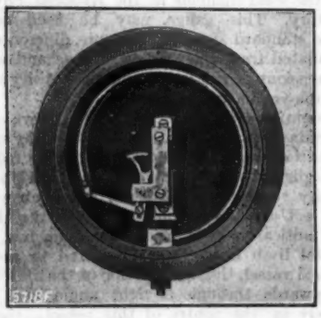


FIG. 31. THE BOURDON PRESSURE GAUGE.

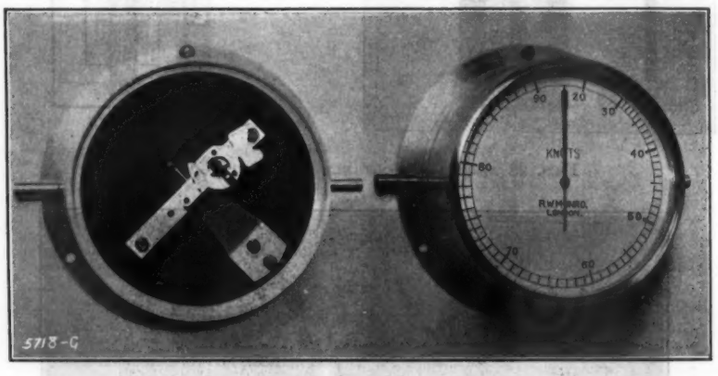


FIG. 32. THE CLIFT INDICATOR.

Fig. 33. THE CLIFT INDICATOR.

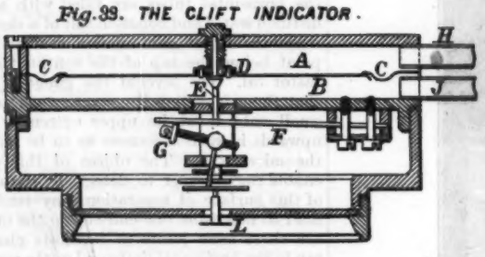
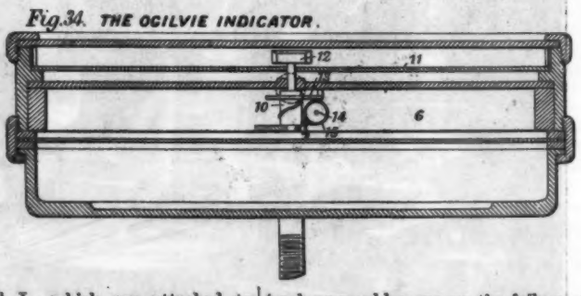


Fig. 34. THE OGILVIE INDICATOR.



* Smithsonian Misc. Coll., vol. lxii, page 34.

section to which the pressure is applied. This tube is bent to form the greater part of a circle and tends to straighten itself under the action of the pressure. The open end of the tube is rigidly attached to the frame of the gauge, the closed end being quite free to move. This free end is connected by a link to a lever at the opposite end of which is a rack gearing with a pinion on the shaft of the indicating pointer. The motion of the tube is thus rendered visible with the desired degree of magnification.

A well-made and properly calibrated Bourdon gauge is usually sufficiently accurate for the class of work it is called upon to do. The chief error is due to the hysteris of the oval tube which causes differences between rising and falling readings; a correction must also be applied for very wide changes of temperature, though steam gauges are always protected by a water seal, and ordinary variations of air temperature may usually be neglected.

Diaphragm Indicators form a class of instrument which is now used almost exclusively on aeroplanes and airships in connection with pressure tube anemometers. It will suffice to deal with two of the better known instruments, viz., the *Clift* and the *Ogilvie* indicators which operate by means of widely different mechanisms.

The *Clift indicator** is illustrated in Fig. 32, both with and without the dial which is calibrated in knots, giving an open scale above 30. The mechanism, which is shown diagrammatically in Fig. 33, consists of an airtight box divided into two separate chambers by the flexible diaphragm C and the light metal disc D. The space A communicates with the pressure side of the head by the tube H, while B is connected to the static (or suction) side by the tube J. When the diaphragm deflects under a pressure difference the motion is transmitted to the rod E, one end of which moves in a guide while the other is in contact with the leaf spring F; the movement of this spring is transmitted to the lever G, which in turn operates the index needle L. A movement of the screw G allows adjustment of the sensitivity to be made, the multiplying mechanism here employed being similar to that often used for aneroid barometers. The mechanism has recently been improved in several important respects, but the exigencies of the present situation forbid the publication of any details.

*The Ogilvie Indicator** (made by the British Wright Company) is shown in the diagram in Fig. 34. The mechanism is so simple that most engineers is very sensitive, certain types giving a motion of the pointer of over 300 deg. for 100 ft./sec., when connected to pitot and static pressure tubes. It is stated that rubber diaphragms have been in use in these instruments for more than a year without showing any signs of perishing; it is a matter of common experience, however, that instruments which use diaphragms of such materials as rubber or leather are more liable to change their calibration than some of the modern instruments in which metal diaphragms are employed. The writer has found that an increase of sensitivity takes place with age. The pointer of the Ogilvie indicator can be deflected to either side of its zero position, an operation which cannot be carried out with the Clift.

The Dines Recorder.—This instrument was designed by Mr. W. H. Dines, F.R.S., for use in conjunction with the Dines head (described on page 263 *ante*), and is shown in Fig. 35. The apparatus consists of a cylindrical vessel filled to a certain level with water in which floats, mouth downwards, a form of bell jar parallel outside, but carefully shaped on the inside to a certain definite curve. The pressure side of the head is connected to the inside of this float by a tube which projects above the surface of the water. The space above the water outside the float is connected to the suction side of the head so that when the wind blows the float tends to rise under the difference of pressure between the pitot and suction tubes. To the top of the float is attached a rod passing through the top of the outer cylinder, by means of a bearing which allows only a very small quantity of air to pass. This rod carries the recording pen which is in contact with a specially prepared chart carried on a drum rotated about a vertical axis by means of clockwork. A guide is provided to prevent rotation of the float.

A record of a gale obtained with an instrument of this type is reproduced in Fig. 36, and it will be noticed that the fluctuations of the wind are reproduced in considerable detail. The uniform scale of velocity graduation is the result of the choice of such a curve for the inside of the float that the rise of the pen is proportional to the square root of the pressure difference acting on the float.

A Sensitive Form of Barometer.

The apparatus described below was used by the writer in an investigation into the changes of static pressure in the atmosphere and really constitutes a barometer for the measurement of very small changes of pressure. The barometer was constructed by Mr. Harris Booth, M.A., and was adapted by the writer for the experiments referred to. The pressure of the atmosphere is balanced by a mercury column connected in the manner shown in Fig. 37, to a standard tilting manometer, and since the space C and all the connections on that side of the manometer are filled with water the true head of fluid is that between the mercury surface G and the water surface F in the tilting manometer. As the experiments were concerned only with *changes* of pressure no arrangements were made for measuring the head which this column of fluid represented. Changes of pressure cause a displacement of the surfaces F and G which displacement is corrected by tilting the manometer until the indicating bubble is in the zero position. By this means changes of pressure of about 0·005-in. of water can be measured, the sensitivity of the tilting manometer being, of course, considerably reduced by connection to the mercury column; if a manometer were made specially for use in this manner the sensitivity could be increased would agree with Sir Horace Darwin who, presiding at the reading of Dr. A. P. Thurston's paper to the Aeronautical Society of Great Britain, said he was afraid he would have placed the Ogilvie instrument in that class, of which one said "what a fool the man must be to think that the thing will work." Work it does, however, and continues to render good service. The mechanism which is illustrated in Fig. 34 consists of a flexible diaphragm (1) of rubber to the centre of which is attached a silk cord (15). This cord takes one turn round the roller (14) and two more round the similar roller (10) to which the other end of the cord is attached. The pivots for these rollers are carried in the frame (6) which spans the instrument, the zero position being maintained by the spiral spring (13). The pointer (12) moves over the dial (11) upon which is marked a practically uniform scale of velocity, a result which is achieved, owing to the particular properties of the flexible diaphragm in spite of the fact that the velocity varies as the square root of the pressure. The device

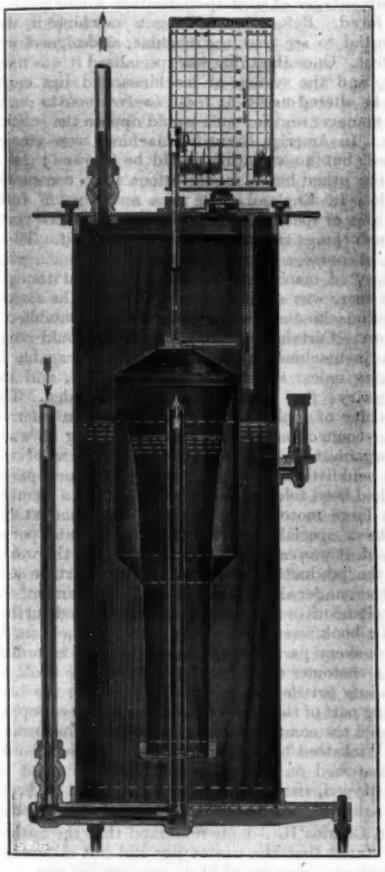


FIG. 35. THE DINES RECORDER.

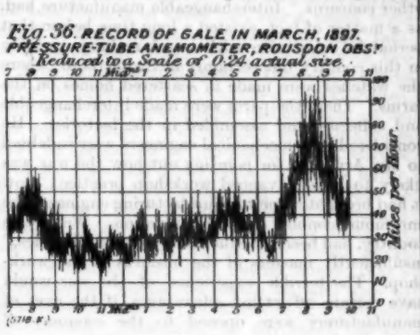


Fig. 36. RECORD OF GALE IN MARCH, 1897.
PRESSURE-TUBE ANEMOMETER, ROUSDON OBS.
Reduced to a Scale of 0·24 actual size.
Miles per Hour.

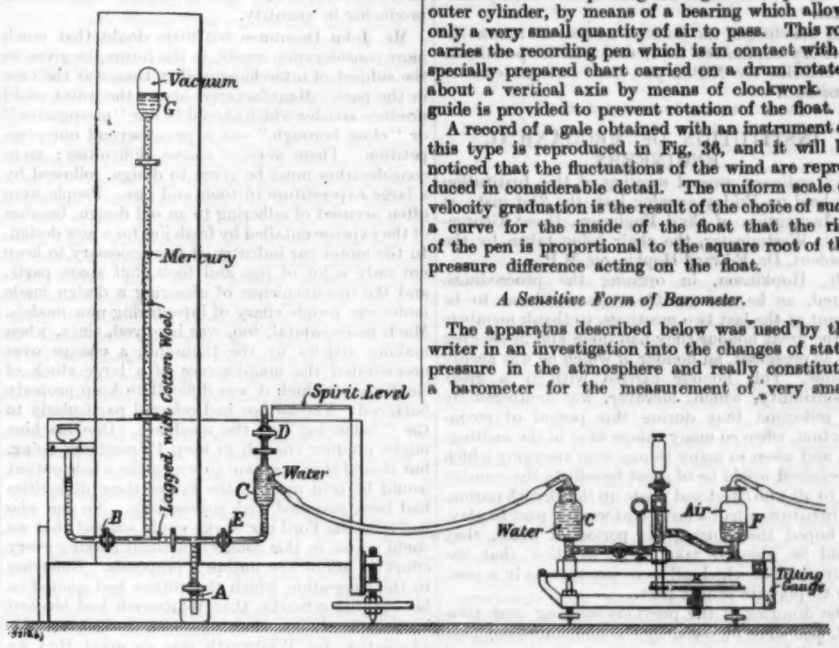


FIG. 37. THE SENSITIVE BAROMETER.

* Described in British Patent No. 1518/13.

* Described in British Patent No. 13796/13.

by reducing the diameter of tube upon which the indicating bubble is formed.

The zero of the instrument can be adjusted to lie within the range of the tilting manometer either by running out mercury at the tap A or running it in at the tap B. The tap D is used for extracting air and the tap E is closed for purposes of transit. It may be noted that by means of this apparatus the errors which are caused in the readings of the ordinary barometer when a wind is blowing can be very readily detected. It is not generally realised that the readings of a barometer are affected by a high wind or that it is not possible to avoid this error by any ordinary location of the instrument. When the barometer is placed in a room its readings will depend, when there is a wind blowing, on whether a window is open on the windward or on the leeward side. In the former case the pressure in the room will be higher than the static pressure by an amount possibly equal to $1/2\rho v^2$ which, for a wind of, say, 80 miles per hour, would amount to more than 0·1-in. of mercury. If a window were open on the leeward side the error would be of opposite sign and would probably be of lower magnitude, though in certain cases the reduction of pressure might exceed $1/2\rho v^2$. The true static (or barometric) pressure could be measured by means of a static tube on a vane exposed to the wind in a position where the flow was undisturbed, connected to apparatus of the kind described above or to the cistern of mercury at the base of an ordinary barometer.

In conclusion the author wishes to thank the Advisory Committee for Aeronautics for permission to describe the N.P.L. yaw-head and the sensitive barometer.

INSTITUTION OF MECHANICAL ENGINEERS.

AN ordinary general meeting of this Institution was held on Friday evening last, the 21st inst., at the Institution of Civil Engineers, Great George-street, Westminster, the chair being taken by the president, Dr. Edward Hopkinson, M.P.

Dr. Hopkinson, in opening the proceedings, desired, as he was unable through illness to be present at the last two meetings, to thank members for the great honour they had done him in electing him as president, an honour of which he was keenly sensible. This honour carried with it a great responsibility, which, however, was tempered by the reflection that during this period of reconstruction, when so many things were in the melting-pot, and when so many things were emerging which he believed would be of great benefit to the country and to all who lived and made up the British nation, the Institution had a large and worthy part to play. He hoped that during his period of office, they would be able to take steps to show that the Institution, of which all were proud, was in a position to play its proper part.

The Minutes of the previous meeting were then read, and were followed by the announcement that 76 candidates had been elected to the several classes of membership.

JIGS, TOOLS AND SPECIAL MACHINES.

The paper set down for reading and discussion was one entitled "Jigs, Tools and Special Machines, with their Relation to the Production of Standardised Parts," by Herbert C. Armitage, of Birmingham, Associate Member. This paper, which was read in abstract by the author, we commence to print in full in another part of this issue, and accordingly proceed at once to the discussion.

Mr. W. Taylor, O.B.E., member of council, opening the discussion, said that when it was considered that about 99 per cent. of those engaged in mechanical engineering were occupied in the workshop, it was surprising that a larger proportion of the time at meetings was not given to workshop topics. Moreover, in the schools much greater attention should be given to the business of the workshop and to the establishment, on firm ground, of workshop science. Mr. Armitage had made a beginning in this direction in laying out certain elements of that science, which he had supplemented by some examples in the economics of machine tools, jigs and appliances used for large production on the one hand and small production on the other. He had also set out certain fundamental guiding principles in the design of jigs and special tools. Mr. Armitage had stated in the paper that standardisation of, or interchangeability in, manufacture, was first introduced in America, at Springfield. The speaker did not believe that was quite correct, but perhaps his friend, Mr. Warner, of Cleveland, would set the point right. He (the speaker) was under the impression that this standardisation and interchangeability was introduced by Colonel Colt, of Hartford, during the Civil War, and that it spread through the Eastern States—by the agency of Pratt and Witney and other concerns. Interchangeable manufacture had, as a matter of fact, existed a long time before that period in connection with watch-making, possibly in this country but certainly in Switzerland, where the watches were made in scattered homes on the farms. There the parts were made interchangeable and collected and assembled in the factories. He considered that mechanical engineers were indebted to Mr. Armitage for pointing out how the war was likely to have advanced workshop practice; how it had brought home to manufacturing engineers the enormous economy of mass production. We, in this country, had been too much of "jacks of all trades," insufficiently masters of the business of the workshop. The terrible experience of the war would have certain off-setting advantages, if the eyes of manufacturers were opened to the economy of producing in quantity.

Mr. John Dewrance felt little doubt that much more consideration would, in the future, be given to the subject of interchangeability than was the case in the past. Manufacturers across the water could produce articles which should be our "prerogative" or "close borough"—at a price beyond our competition. There were, of course, difficulties; more consideration must be given to design, followed by a large expenditure in tools and jigs. People were often accused of adhering to an old design, because of the expense entailed by fresh jigs for a new design. In the motor-car industry, it was necessary to keep not only a lot of jigs and tools, but spare parts, and the inconvenience of changing a design made motor-car people chary of introducing new models. Much more capital, too, was involved, since, when making articles by the thousand, a change over necessitated the maintenance of a large stock of small parts, which it was difficult to keep properly balanced. The author had referred particularly to the "balancing" of the machines. One machine might produce enough to keep 12 machines going, but should that machine go wrong the whole output would be held up. In the States these difficulties had been grappled with successfully. No one who had seen the Ford car works would suggest that we could go on, in this country, without making every effort to adopt the author's proposals. Referring to the suggestion which the author had quoted in his opening remarks, that Whitworth had blocked interchangeability and mass manufacture, his admiration for Whitworth was so great that he would be slow to admit the charges. He felt that the accuracy of Whitworth's work had made the interchangeable system possible, though American engineers might lay claim to the next tage.

Mr. W. R. Warner, of Cleveland, past-president of the American Society of Mechanical Engineers, quoted an example of the advantage of special jigs and fixtures. In the States 4 hours were required to machine, on tool-room methods, a worm gear wheel for one of the fire-control instruments. The job called for great accuracy and care, and Brown and Sharpe machines were used. The gear was made of steel, and one hour of the four was taken up in getting the little burr off the edge of the teeth. An error of 3 minutes of arc was allowed. On the work being undertaken by a firm with which the speaker was acquainted, the whole job was done in 10 minutes, with suitable jigs, &c., with a error of 1 minute of arc instead of the allowed 3 minutes; the burr was taken off automatically as it was made. That was one illustration of the benefits of special jigs and fixtures. "Organisation"—a word which commended itself to the speaker—was frequently used in the paper, and, in this connection, he would refer to the proceedings of the Standard Oil Company. This company took an expensive material from the earth, refined it by an expensive process, and delivered it at the garage or kitchen door, all over the world, at a price less than that of a bottle of water which ran down the hillside. That was accomplished by organisation, and he would ask if any stronger example of its effect were needed. He was at the Poland Springs, in Maine, some two years ago, and it would emphasise the power of organisation if he said that the spring water, which was supplied free in hotels, &c., cost 80 cents a gallon outside, whereas 20 cents per gallon were paid for gasoline and 10 cents for kerosene.

Mr. Charles Wicksteed agreed with the author's view that business methods would have to be greatly changed if manufacture was to exist in the future; much more would have to be done in the way of specialising and building jigs, &c. Specialisation did not mean all-round gain, and the dangers and disadvantages of over-specialisation would have to be faced. Before specialising a machine it was essential to see that the machine, as designed, was perfect. Once the thing was specialised it was fixed fast, and the system of machines and jigs could not be altered under at least twelve months; and the manager and foremen would oppose the suggestion. In America beautiful machines were stereotyped, but no variation would be allowed; here, on the other hand, modifications were constantly made. In England there was an aversion from the idea of specialising, and as a consequence trade in such things as lathes, &c., had been lost. There was, of course, a convenience in firms making a great variety of machines, and Mr. Wicksteed thought that there was a middle course between the stereotyped machine and our own somewhat "muddled" system. Certainly our manufacturers would never make a machine as good as they were capable of making unless specialising were adopted, and the necessary jigs and apparatus provided. The difficulty of replacing old parts had been referred to in connection with motor cars, owing to want of organisation, and certainly the makers of the cars paid little attention to the supply of new parts. He had been told by an American friend, a member of a large motor firm, that the latter had at his works a special department for duplicate parts. In fact, it was essential to use one part of the works for the production of the stereotyped article and another, under altogether different management, for miscellaneous work. His friend had stated further that a book was issued at the works in question, in which every part of every motor car was recorded, and a customer could be supplied with the book, or with any article "by return." This was the best paying part of the business, and the system of supply assisted the commercial connection. In conclusion, Mr. Wicksteed urged that the utmost pains should be bestowed on the design of the machine to be stereotyped, that a record of parts should be kept, and a department maintained to supply those parts.

Mr. Charles H. Adams remarked that the author had stated that the use of jigs did not encourage individual ingenuity, skill or resource, except in a small section of the labour employed. The speaker considered that the use of jigs and labour-saving devices generally did tend to make operators automatic. But it was possible, with mass production, to work shorter hours, pay higher wages, produce more, and sell at a cheaper rate with a good profit and a quick return. Consequently the worker had more leisure to spend, either in improving his mind at home, or at a club, or in some sport. This should compensate for the loss of individual ingenuity. Mr. Armitage had contended that the British employee did not like organisation. It was, the speaker thought, a question of getting into line or going under. On the question of the right design of jigs and tools, and the disasters incidental to incorrect manufacture, raised by the author, the speaker agreed, but attributed the fault to the insufficient status accorded to the designer or draughtsmen—certainly in bygone years. A man used his ability as a draughtsman merely as a means to becoming a works manager or the like. Accordingly, after a certain amount of experience the draughtsman passed to another job. The remedy was to make the status of the draughtsman quite different. With regard to standardisation, there

seemed an aversion from installing new plant in this country. Many engineers would run a plant to death, would never shut down for repairs, and would then be surprised at a breakdown. A machine should be regarded as an investment; when it had gained a good profit it should, irrespective of whether it could be used or not, be scrapped and replaced by a new machine, any possibility of breakdown being thus avoided. Mr. Wicksteed had emphasised the necessity for perfecting an article before manufacture. The speaker was in agreement, but feared that the average manufacturer wanted immediate results or dividends; if he would wait for results proper standardisation might be effected. If it were possible to start in a small way, with adequate capital behind the venture, and work on a design and step by step to perfect it before the machine was manufactured; then to lay down plant and wait for a return on outlay the result might be good. With regard to the list of operations for connecting rods, given in the paper, in Table III, he would like to suggest that, between operations 11 and 12, the parted surfaces should be lightly surface ground or milled before bolting together took place, in order to give correct form. In connection with the scheme for large production, there was shown (Fig. 11 of the paper) a duplex jig for rough milling rods, while in Figs. 5 and 6 two other jigs were shown, for the same operation. The speaker suggested that the two latter jigs would be more profitably employed in large production, because loading and unloading could be more quickly effected with the two machines. Alternatively, the jig shown by Fig. 11 could be used for both productions. The cost of making the one jig would be smaller than making the two, and in any case only two rods were being milled at a time. In commenting on the disadvantage of this type of jig, swinging round through 180 deg., the author remarked that a small inaccuracy in the alignment was magnified in the work. That was so, but the speaker would suggest that the index plunger shown in Fig. 11 should remove any trouble in getting alignment; indeed, he supposed that to be its purpose, and if the circular pin would not do away with error in alignment some other provision should be made. There should be no possibility of getting the job out of alignment, whether skilled or unskilled labour were used. With regard to Fig. 12 of the paper, showing a jig for four-spindle drilling, he suggested that, in place of the handle the jig should be run on rollers with stops. This would save time, if only a few seconds, in winding the screw to bring the bushes under the drill. If placed on rollers, the jig could be pushed clean away from the drilling machine, for loading and unloading. Finally, Mr. Adams referred to the author's remark that the tendency of tool design was in the direction of "fool-proof" jigs, therefore making more complex and larger jigs necessary. Evidently Mr. Armitage had contemplated the possibility of jigs being made which were not "fool-proof." That possibility might exist, although he (Mr. Adams) would contend that every jig put into a shop should be "fool-proof." If there were two ways of getting a job into a jig it was quite possible that on the tenth occasion it might go in the wrong way.

Mr. Herbert Carpenter referred to Tables I and II of the paper, remarking that the labour rates in the case of Table I must be war rates, while they must be pre-war rates in the case of Table II. The author had said that marking out was unnecessary with jigs, but the speaker believed that marking out was not, in many cases, done so much with the idea of positioning, as of proving a casting, and it was also useful for locating. The speaker had never found a jig which would locate the monoblock for an engine which had an unmachined surface at the top of the head. Mr. Armitage had referred to the auto-engine connecting rod as a straightforward job, but that was not so with the aero-engine connecting rod. The speaker had been connected with a works laid out to produce 100 aero-engine sets per week; that involved 800 connecting rods, or, with spares, considerably over 1,000. There was trouble with every operation, and to finish the jobs off they had to be hand reamed in a jig. Probably the causes were war-time hurry and flimsiness of the rods. With regard to the claim of the Becker Company to produce 90 connecting rods per hour, representing 4,000 per week, or 1,000 four-cylinder engines per week, the speaker did not think that the most optimistic firm in England would anticipate the production of 1,000 cars per week. Turning to organisation, the greater the organisation the greater the production. He would suggest, in this connection, that the Government should call the motor car manufacturers together and get them to form a committee to consider standardisation. There were to-day 200 or 300 cars on the market with not so much as a piston ring standardised. Such a committee might develop designs embodying the best features of every car, and a dozen types might be standardised, embracing light cars, taxi-cabs, lorries and trading vans, together with two or three other essential types. They could evolve five or six types of engine and one or two magnetos, while they could standardise carburettors, valves and piston rings. The making of small fittings could be specialised by the smaller firms, engines by larger firms, and motor cars by firms still larger. With such a system connecting rods should be produced at a cost of 10*d*. per rod, and generally the price of cars be reduced to pre-war limits. It might be urged that the scheme would arrest improvement and invention, but he thought that a manufacturers' committee would be well able to judge of the desirability or otherwise of a proposed improvement. Personally, he advocated the extension of such standardisation beyond the manufacture of motor cars—to every branch of the engineering trade. No attempt was at present made here to bring the manufacturers together, for the purpose of organising production, so that they might compete with foreign countries.

Mr. J. J. Guest attributed the origin of modern American methods of manufacture to the Civil War, but as Mr. Taylor had said the principle of interchangeability had been applied to watches. There were one or two points in the history of watch-making which would repeat themselves unless carefully borne in mind. At first one man made one watch, which was an expensive method. As quantities developed efforts were made to throw as many operations as possible upon one machine, with consequent reduction in price. The complicated machines, however, required a large number of tools; some would have seven spindles doing a variety of operations on one part, and if anything went wrong with one tool or spindle the whole machine was held up. In watch-making in Switzerland the modern practice was for one machine to do one operation, or at any rate only a few operations. Of late, guns, rifles, pistols, sewing machines, type-writers and bicycles had been practically brought under quantity manufacture. He would divide world manufactures into three classes. Single production, as of ships; only since the war had the ship been standardised for cheapness and rapidity of manufacture. Articles like pins and needles, on the other hand, were wanted by the million, while a host of things were wanted in moderate quantity. A pin factory could not exist unless plant and operations were of the best; the price was cut to the limit, while the article was fixed in design. In single-article production there was no fixation of design, nor could the intermediate products be of fixed design. With regard to motor cars or engines, which could not be of perfect design, he would ask what would happen if the industry were organised for large and cheap production, and it was shown that a better engine could be produced? It would mean the scrapping of much material, so that there was a limit, set by the state of the market, to fixed design. With a big market and large quantity sale, expenditure on jigs and special machines could be adjusted to suit. Mr. Guest considered that the market in this country was more in favour of the American manufactures, while the American was closed to British productions; this gave the Americans a better chance of big sales, and justified them in putting down far better plant and aiming at a higher manufacturing output. Sale of output was, of course, the first essential. In manufacturing in quantity, cost was dependent on the limits allowed. If a large limit were put upon a part it would go into place at once, whereas if the limit were fine this would not be so readily done. Nevertheless the resulting machine would be better, because the wider limit would be equivalent to so much wear of the machine. In making a standard car the decision as to the limit allowed was important. The speaker anticipated trouble in the factories over certain points in connection with specialised manufacture. The rule of one man one machine rendered the use of quick methods of no advantage; something slower might just as well be used. He thought it would be beneficial if a lot of large firms would expose their times for standard operations, and, from these, time tables or charts might be made up which would be accepted as reasonable, for instance, for keyways of a certain length, width and depth. If so accepted, there would be little dispute as to the average of times submitted by the drawing office or management to the shop as a whole.

Mr. William H. Patchell, member of council, felt that the learned institutions had been very keen on the scientific side of engineering work, but had not paid sufficient attention to cost of production. The paper presented that point very clearly. Those who had served their time in the shops found a diversity of work, and when, as they grew older, they were asked where boys should be sent they recommended small shops on account of the diversity. It was very essential now that work should be turned out more cheaply. For such reasons he thought that institutions should encourage papers on production. Mr. Guest had referred to the giving of times by manufacturers. During the war much had been heard of men pitch-forked into wrong places, and engineers had jibbed at men, not of the cloth, being put in charge of works. He had experience, however, of an accountant who had justified such a position. Not being satisfied with the total costings, he got to know details of other people's costs and went round and bullied his shop managers and foremen until he had secured the minimum cost of the various operations, and he finished by getting a total time less than that attained anywhere else. Mr. Carpenter had referred to dividing the work among various shops. An example of this was already afforded by the case of certain standard engines. He agreed that the small shop, as such, would have to take to manufacturing special parts for other shops.

Mr. L. A. Legros wished to direct attention to the fact that some of the earliest work of a high degree of accuracy was done in the method of die-casting for type for Moxon, in 1680. In fitting the type together, the limit was a quarter-thousandth, as could be seen from the lock-up pages, &c., printed at that time. In 1760, Fournier discovered that it was necessary to have a system of units for the growth of sizes in the various parts which made up into a composite whole. During the war die-casting had been carried out for such operations as the casting of white metal into bearings, but previously this was unknown. Whitworth when working on the Babbage calculating machine, which had to do printing, had endless trouble with screws and parts not interchangeable, and this led him to devote his attention to gauges and standard screw threads. The author had remarked that there was every reason to believe that skilled workers would realise that their welfare depended upon maximum production; that granted, successful production depended upon organisation and special tools. Mr. Legros observed that the design must precede the tool, and that demanded the employment of the skilled man. The man brought up in small shops and under difficulties attained great skill by reason of being deprived of the very things necessary for production. The author had made a strong point of eliminating marking out, but the speaker considered that too much importance could not be attached to this matter. One of the great troubles of production was keeping the jigs clear from swarf, so that parts might not be dropped in until the swarf was got rid of. Making the spotting pieces suitable to give an outlet for the material cut away, and the prevention of the growth of error in the successive jigging operations, were matters of importance. He would ask the author, in replying, to indicate the limit of amount which a tool would cut; with too small an amount, the tool would refuse to cut, while with each material there was a limit at which the tool would rapidly wear out if given less than its proper amount to cut. With regard to the influence

of assembling on production, in America woman labour was quite usefully employed in assembling telephones and a number of other parts; but when it was a question of sewing machines or typewriters, which had to be put to work in unskilled hands, the question arose as to whether the machine would be just in the condition it should after running for a day or two; whether every part had sufficient play to prevent the machine from being too stiff, or behaving in any of the many ways in which such machines behave once out of the manufacturer's and into the seller's hands. Perhaps the author could touch on that point in relation to production by the methods he had named.

Mr. H. C. Armitage, in reply to the discussion, agreed that independent gauging was first introduced by Colonel Colt, the idea being brought into being by the mass production needed for the Civil War. The grandfather of a friend of the speaker was connected with the Waltham Watch Company, and his friend remembered his grandfather going to the Springfield Company in America, to study their methods of producing things by independent gauging. It was that fact that led him to the view that watch-making followed small arms in regard to interchangeable production. In relation to capital, mass production, of course, required large capital. There was, however, a definite science of tool design, naturally not an exact science; but the speaker had no fears in respect to capital so long as tool designing was in the hands of an experienced and scientifically-trained man. On the subject of draughtsmen, general practice had regarded them merely as draughtsmen, a little superior to a clerk, whereas a draughtsman should be shop-trained and should have one of the best brains in the works. A draughtsman should be not only a man with experience in operating machines, but one who was equal to responsibility for manufacture. Given an opportunity of designing tools and trying his methods in the shop, such a man should in a few years be trusted to design jigs and tools for producing articles. During the war, unfortunately, jigs and tools had not met anticipations without much experimenting and discussion on the part of the tool draughtsmen. With regard to "balancing" in the machine shop, that question was worthy of study as a problem in organisation and of being put before the Institution. If one machine overtook another, and had to be stopped, what, meanwhile, should be done with the operator? Men should at least know three or four operations. When work was piling up against a machine, the organisation should be such that the idle man should be sent to that machine. Organisation, the speaker said, could be carried to an extreme, to a dead end. By way of instance, he pointed out that it was decided not to have a standard design of aeroplane, and he attributed the success achieved in the war to that fact. Nevertheless, there was no reason why three-quarters of the aeroplanes should not have standard parts; there was no reason why one should have $1\frac{5}{8}$-in. bolts and another $1\frac{1}{4}$-in. bolts. With reference to the supply of spares, he believed that matter was dealt with effectively in America. In this country there were, however, firms who made a living by supplying spares. Sometimes more money was spent on spare parts of a machine tool than that originally paid for the machine tool; for once the tool was bought the purchase of spares from the firm was unavoidable. Similar conditions were to be met with in the motor-car trade. With regard to the parting off of the connecting rod and the suggestion that the two pieces should be ground, experience had shown this to be unnecessary; certainly the speaker had never seen it done. One critic had raised the question of the quantity of connecting rods required, but as the same rod served for a car, a lorry, or a tractor, the quantity was quite safe. Reference had been made to the indexing plunger on the jig. That was a tool-making proposition. To get two holes at dead right angles to one another, with sufficient accuracy to produce two parts absolutely in line was an interesting problem, and was much more difficult than getting two holes at a space of a quarter-thousandth. As to whether it paid to put simple jigs in for a lot of operations or have a complicated jig to perform a number of such operations, he, personally, had no faith in the complex jig; cheaper labour could be used with the simpler operation. With regard to marking out monoblocks, mentioned by Mr. Carpenter, such marking out was unnecessary if a jig were employed to do it, a jig which would locate the particular points required by the casting. The speaker considered hand-reaming of mass-produced parts to be absolutely necessary, on account of the high limit on the parts. He would instance a connecting rod bedded to its bearing on the crankshaft; it was undesirable to bed this bearing down on to the crankshaft, or to bed the crankshaft down on the bearing in the crank-case; hand-reaming was absolutely necessary in that case. Assuming tolerance between crankshaft and bearing to be half a thousandth, the reamer would be opened out to that size, and in that case the crank-shaft would have to be measured. Standard piece-work times should be possible, the speaker considered, but once established it could not be departed from without a general strike. In the speaker's works it had been applied to cutting off; a rate-fixer was dispensed with, the cutting-off shop setting its own rates by means of a graph. Mr. Legros had referred to swarf, and that was a case in which the simple jig was ahead of the complex one; the swarf could be easily pulled out.

The machining of short allowances was a very important point, and there was often great difficulty in machining fine stampings or castings. Fortunately both foundry and stamping shop were usually paid by weight, and dies were consequently designed to get as much metal as possible. It was only by supplying drawings of the parts, and suggesting that no one other than themselves knew how to make stampings or dies, that these departments could be induced to overcome their prejudice against their own design and machine allowances being put on the parts. Satisfactory results were never obtained with small machine allowances; a good margin paid. With regard to assembly limits, he had mentioned in the paper that two or three further sets of limits were required; the systems in existences were far from perfect. Indeed, he thought the subject worthy of the attention of the Institution. Certain classes of work required their own limits.

On the motion of the president, a vote of thanks to the author was passed by acclamation.

The president then announced that the next ordinary meeting would take place on Friday, May 2, when a paper would be read on "The Mechanical Properties of Steel, with Some Consideration of the Question of Brittleness," by Dr. W. H. Hatfield, of Sheffield, Associate Member.

The proceedings then closed.

H.M. SEAPLANE-CARRYING SHIP "ARGUS."

ONE of the most interesting ships added to the Navy during the war was the seaplane-carrying ship Argus, built by Messrs. William Beardmore and Co., Limited, at their works at Dalmuir on the Clyde. It is true that the Admiralty adapted the battle cruiser Furious to accommodate seaplanes and to permit them to rise from the deck, and this vessel, with her 90,000-h.p. geared turbine machinery, had a speed of 32 knots, which gave her a great advantage over the Argus in point of speed. Further, there is now being built specially for the same duty the cruiser Eagle, also of high speed and specially adapted to enable seaplanes to rise from her deck. The Argus, however, has the advantages that there is absolutely no obstruction on the flying deck, not even funnels, and that she has under this deck, space for the accommodation and repair of seaplanes. She is therefore a floating hangar, the space given up for this purpose being 330 ft. long, 68 ft. wide over all, and 48 ft. clear, with a clear height of about 20 ft. Hoists are provided from this hangar to the flying deck, and cranes are available for lifting the seaplanes from the water on to the hangar deck. The structural arrangements in the ship to meet these abnormal conditions involved problems of design and construction which were admirably worked out and proved thoroughly successful. Perhaps however, the most novel feature is the arrangement of the uptakes from the funnels, so that the boiler furnace gases could be discharged over the stern. Here also gratifying success has been achieved, and the results reflect credit not only on the technical officers of the Admiralty but on those responsible for the building of the ship and her machinery at Messrs. Beardmore's works.

In view of the novelty of the vessel the longitudinal section which we publish on the opposite page and the series of perspective views of the ship and the hangar on pages 401 and 408 and Plates XXIV to XXVII will be studied with interest. In a subsequent article we hope to publish drawings showing the boiler uptakes with their horizontal connections for the discharge of the flue gases over the stern.

The vessel illustrated was laid down originally as a first-class passenger and cargo steamer for the Lloyd Sabaudo Company of Genoa, but work on her was discontinued at the outbreak of war. In 1916, however, the Admiralty decided to have her completed as a seaplane carrier, although the construction of the hull was in an advanced state, and it was not possible therefore so to alter it as to ensure a high speed. Modifications however, were made to increase the power and raise the speed from 18 knots under normal sea conditions to $20\frac{1}{4}$ knots for short periods and 20 knots on service in ordinary weather. As originally designed and built the vessel was 535 ft. long between perpendiculars, of a moulded breadth of 68 ft., with a height of 40 ft. to the shelter deck. The original form, structure and decks were retained up to the shelter deck, which it was decided should constitute the floor of the hangar. Thus all above the shelter deck was modified to provide hangar, workshops, stores and a flying deck.

In the early stages of the design of the superstructural work the method of supporting the flying deck was carefully considered. A $\frac{1}{4}$-in. scale model of the ship according to the proposed method of construction was sent to the National Physical Laboratory at Teddington to be tested in the air tunnel there. Exhaustive experiments on this model were carried out for the purpose of discovering the eddy-making effect of the structural work below and above the flying deck, and also about the after end, through which air eddies the aircraft had to pass when alighting on the deck. The result of these experiments showed that to ensure the minimum of air disturbance it was necessary that the space between the hangar roof and flying deck should be as open as possible. On account of this it was decided to make the hangar roof strong enough to withstand the greatest hogging and sagging stresses likely to come on the structure and to support the flying deck by very light lattice work, as shown in Figs. 1 to 5. In addition, expansion joints were introduced at various points to ensure that no stresses were to be taken up by the flying deck. Further, it was discovered that the emission of the hot gases through vertical funnels above the flying deck produced such serious air disturbance that the safe landing on the deck would be extremely difficult. This necessitated the fitting of the horizontal smoke ducts below the flying deck which carry the gases right aft away from the stern. A striking feature of the design, as shown in Figs. 1 and 2, is the great overhang aft about 85 ft. abaft where the side plating ends, and the special arrangements for effectively supporting and anchoring this to the general structure.

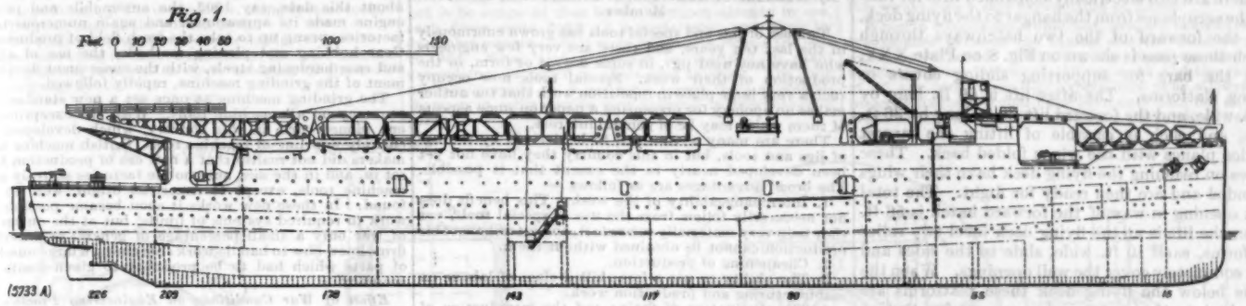
The longitudinal section (Fig. 1) shows the arrangement of the hangar, the flying deck without obstruction, the wireless masts being at the side, as more clearly indicated in Fig. 2, which shows the vessel on her steam trials, while Fig. 3 is from a photograph taken at the time when a smoke "cloud" was being produced abaft the ship. Figs. 4 and 5, on Plate XXIV, give two views of the vessel in Beardmore's fitting-out basin under the 150-ton hammer-head crane.

The hangar, designed to fulfil the latest requirements of the Air Board for this type of ship, is 330 ft., long by 68 ft. wide over all, and 48 ft. clear width, and is of a capacity regarded as sufficient to accommodate 20 seaplanes. Fig. 17 on page 408 gives an excellent genera view of the hangar. To support the side plating

H.M. SEAPLANE-CARRYING SHIP "ARGUS."

CONSTRUCTED BY MESSRS. WILLIAM BEARDMORE AND CO., LIMITED, NAVAL CONSTRUCTION WORKS, DALMUIR.

Fig. 1.



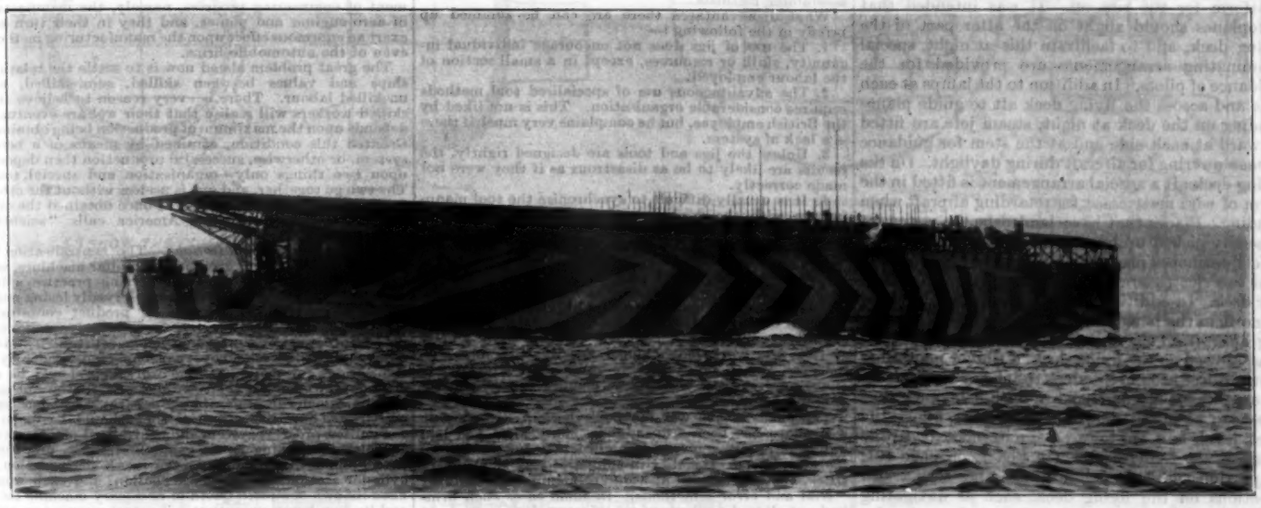


FIG. 2. VESSEL ON STEAM TRIALS.

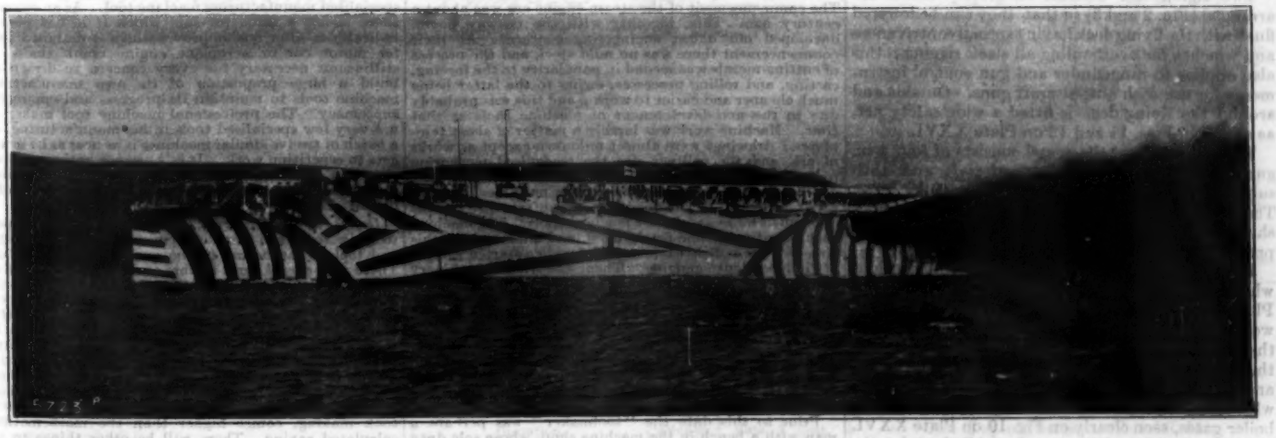


FIG. 3. VESSEL PRODUCING SMOKE-SCREEN.

of this hangar deep web frames were carried up along the ship side to a height of about 25 ft. 6 in. above the original shelter deck. The roof was strongly constructed of steel on widely space transverse girders and longitudinal beams, as clearly shown in Fig. 6 in Plate XXV and Fig. 17 on page 408. The girders are at such a height as to give about 20 ft. clear headroom in the hangar. The hangar itself is divided into four spaces by transverse fireproof curtains, fitted for the full height of the hangar. Fig. 6 is a view of the interior wall of the hangar on the port side, showing a thermo-tank heating unit, radiators, racks for carrying torpedoes and the overhead runway for transporting biplanes. Fig. 7 shows the ventilating unit in the hangar, with store rooms and corresponding torpedo racks, on the starboard side of the ship. In these store-rooms are accommodated spare parts, wings, propellers, torpedoes and bombs. Immediately forward of the hangar are large workshops for engineers and carpenters, fully equipped with machine tools for the rapid repair of damaged parts of aircraft. Easy access to these workshops is obtained through large fireproof doors in the far end of the hangar. Fig. 9 shows part of the workshop equipment, as it illustrates the test house for aeroplane engines and propellers, which has a protective netting round it.

The flying deck is 68 ft. wide, is fitted all fore and aft at a distance of 14 ft. 6 in. above the hangar roof, and is clear of all obstructions. The navigating bridge, bridge houses, wireless offices, &c., is placed forward under the flying deck. The chart house is capable of being raised above the flying deck level or lowered to a stowing position under the flying deck by hydraulic power, and when in raised position commands a clear all-round view. Fig. 16 is a view under the chart house when lowered, showing the pumps, and

hydraulic ram used for lifting the chart house, which fits in guides on each side. The chart house raised is seen at the top of the view, Fig. 8, on Plate XXV.

There are two electrically-controlled lifts for raising the aeroplanes from the hangar to the flying deck, and the forward of the two hatchways through which these pass is shown on Fig. 8 on Plate XXV, with the bars for supporting sliding covers or sliding platforms. The after lift is 60 ft. long by 18 ft. wide, and the forward lift 30 ft. long by 36 ft. wide, and each is capable of lifting the largest Service planes with the wings folded back. These planes on reaching the flying deck have their wings extended and are then ready for flight. The total deck opening in way of the forward hatch is 56 ft. When the lift is at the flying deck level two roller platforms, each 10 ft. wide, slide to the sides and thus completely cover the well openings. When the lift is below the flying deck these platforms are brought into the centre and give a 20 ft. starting platform for the run off. It was intended that aeroplanes should alight on the after part of the flying deck, and to facilitate this at night, special illuminating arrangements are provided for the guidance of pilots. In addition to the lamps at each side and across the flying deck aft to guide planes landing on the deck at night, steam jets are fitted forward at each side and at the stem for guidance in manœuvring for aircraft during daylight. On the flying deck aft a special arrangement is fitted in the form of wire mattresses, for retarding aircraft when landing. Planes that have landed in the water are specially picked up by means of two derricks with electric winches placed amidship on the flying deck, and two electric cranes abaft the hangar on the hangar deck. In addition to the stowage arranged for aircraft in the hangar, provision is made for carrying aircraft on the flying deck. When aircraft are thus stowed on the flying deck, a timber palisading can be raised around this deck to act as a wind screen. The palisades are arranged in such a manner that they can be raised simultaneously 14 ft. above the deck level, and are lowered simultaneously to the flush of the flying deck. On Fig. 2, on page 401, a portion of the palisade can be seen. All erections on the flying deck, such as navigating and chart house jack and ensign staffs, poles for navigating and signalling lights, are arranged so that all can be lowered flush with the flying deck.

Two signal and wireless telegraphy masts are arranged (Fig. 2 and 3) so that they can be lowered flush with the flying deck having special contrivances and winches for overhauling all slack rigging; this also applies to rangefinder and gun control instruments for use with anti-aircraft guns. Outside and around the flying deck is fitted a wide safety net, as shown in Figs. 11 and 12 on Plate XXVI.

The armament of the vessel consists of four 4-in. guns of special type for anti-aircraft and anti-submarine protection, and two 4-in Q.F. guns. These are placed in suitable positions forward, amidships, and aft so as to afford all-round and overhead protection.

Reference may be made to those illustrations which have not so far been dealt with. Fig. 14 on Plate XXVII is a bow view of the vessel, and shows well the stanchions for carrying the flying deck. On the same plate is a stern view showing the stern guns, the cranes for lifting the seaplanes from the water, and the great overhang of the flying deck, under which are the fans and discharge funnels of the boiler gases, seen clearly on Fig. 10 on Plate XXVI, while the horizontal "camouflaged" duct for the gases is seen on Fig. 13 on the same plate. These details will be fully described in our next article.

(To be continued.)

THE ROYAL SANITARY INSTITUTE.—This Institute will hold a Congress at Newcastle-upon-Tyne, from July 28 to August 2, 1919. The president of the Congress is to be the Duke of Northumberland, and the arrangements for the meeting will include: General Addresses and Lectures; President's Inaugural Address; a Lecture to the Congress; and a Popular Lecture. Sectional meetings will be held for the reading and discussion of papers relating to: "Sanitary Science and Preventive Medicine"; "Engineering and Architecture"; "Hygiene of Maternity and Child Welfare"; "Personal and Domestic Hygiene"; and "Industrial Hygiene."

JIGS, TOOLS, AND SPECIAL MACHINES, WITH THEIR RELATION TO THE PRODUCTION OF STANDARDISED PARTS.*

By HERBERT C. ARMITAGE, of Birmingham, Associate Member.

THE use of jigs and special tools has grown enormously in the last ten years, and there are very few engineers who have not used jigs, in some degree or form, in the production of their work. Special tools now occupy such a very large place in repetition work that the author makes no apology for presenting a paper on some aspects of them which may be of general interest.

There are many advantages to be derived by the use of jigs and tools, but in this country they have not yet been developed nearly to the extent that is possible. The broad advantages are as follows:—

1. Interchangeability of the work. This benefit does not necessarily follow from the use of special tools, yet they help very materially towards it, and interchangeable production cannot be obtained without them.
2. Cheapening of production.
3. The ability to use a less skilled class of labour on manufacturing and production work.
4. The elimination of fitting and the introduction of assembling methods.

What disadvantages there are can be summed up briefly in the following:—

1. The use of jigs does not encourage individual ingenuity, skill, or resources, except in a small section of the labour employed.
2. The advantageous use of specialised tool methods requires considerable organisation. This is not liked by the British employee, but he complains very much if there is a lack of system.
3. Unless the jigs and tools are designed rightly, the results are likely to be as disastrous as if they were not made correctly.
4. It is usually difficult to synchronise the tool manufacture with the desired production of manufactured parts, due chiefly to the fluctuating requirements of the producing departments.

The ideal system which a firm should cultivate is simply to become staffed and arranged in such a way that full use can be made easily and quickly of a correct relationship between the planning department, the progress department, the tool office, and tool-room. If there is a solid foundation upon which to build a good system, the works can expand rapidly with increased business, and in addition there will be little difficulty in changing over from one type of manufacture to another of similar construction.

The effect of the war upon production conditions in workshops has been stupendous. Many firms had laid out their works more or less efficiently for the manufacture of some speciality in comparatively small quantities, and had arrived at accurate manufacture only by "trial and error" methods. In some cases such firms had not altered methods of manufacture for many years, unless forced by competition. In this connection, it is interesting to study the types of works organisations in existence in this country at the outbreak of war.

Development of Engineering Manufacturing Methods.—The commencement of the steam-engine era was about a century ago. This, together with the railway boom, developed our oldest engineering concerns. At their commencement there was no mild steel, and the process of cutting metals was second in popularity to the forging, casting, and rolling processes, owing to the latter being much cheaper and easier to work; and this was probably due to the non-development of machine tools at that time. Machine work was largely a matter of sheet templates; drawings were almost unknown except as works of art, and the calliper was the recognised measuring instrument. Swiftly following this period came the general development of power-driven machines, and the rapid growth of engineering manufacturing works demanded more and better machine tools. The machine tool industry became firmly fixed, and almost about this time the Springfield Company of America started the use of independent gauging. Then electrical machinery came into use, and in its wake numbers of new electrical manufacturing concerns were instituted all over the country. These firms in their early days were able to use mild steel, the telephone, electric driving and lighting, turret lathes, and early automatic machines; and, the author believes, were amongst the first to develop the use of drilling jigs, on large size work chiefly, owing to electrical machines being more easy of standardisation than previous engineering products.

Prior to this date the "toolmaker" was perhaps a man with a bench in the machine shop, whose sole duty was to repair chucks, "peg" broken gears, &c., and any machining he required was done in the general shop.

The electrical machine, however, necessitated the extensive manufacture of press tools, and gradually the tool-room idea was developed, namely, to make tools entirely without interference with production work. Unfortunately, like the pattern shop, the tool-room appeared to have a non-productive aspect, because the goods it made were not directly saleable. The then works managers, therefore, would generally start reducing costs in that department when any criticism of works expenses arose.

The importance of the tool-room grew but slowly until the introduction of high-speed steel, which again revolutionised shop practice. Then followed a rapid extension of the "closed-in" department, due probably to the fact that high-speed steel could not be worked upon by all. The milling machine and its cutters were developed, any cut gearing had to be used in machine tools. The grinding requirements of the cutters gradually evolved the tool store, and this, combined with the increasing use of jigs and the increasing importance of the tool-room, made a tool drawing office absolutely essential. At about this date, say 1902, the automobile and petrol engine made its appearance, and again numerous new factories sprang up to take the fresh field of production. Gear hobbing and planing methods, the use of alloy and case-hardening steels, with the consequent development of the grinding machine, rapidly followed.

The grinding machine at once set a new standard of accuracy on all machine tools. With the exception of one pioneer firm in this country, which developed an entirely new line of machine tools, British machine tool makers did not realise that a new era of production had set in, and in the new automobile factories scarcely any machine tools, except of American origin, were to be found. In these new works it soon became possible to work to required systems of limits, but at the outbreak of war only a small percentage of general engineering firms knew how to handle work containing a large number of parts which had to be produced to given limits of accuracy.

Effect of War Conditions on Engineering Practice.—The period of the war has seen another rapid development of engineering progress, namely, the manufacture of aero engines and planes, and they in their turn will exert an enormous effect upon the manufacturing methods even of the automobile firms.

The great problem ahead now is to settle the relationships and values between skilled, semi-skilled, and unskilled labour. There is every reason to believe that skilled workers will realise that their welfare eventually depends upon the maximum of production being obtained. Granted this condition, attained by means of a bonus system, or otherwise, successful production then depends upon two things only—organisation and special tools. The two go together, and one is useless without the other. Combine the two, and there is at once obtained the only desirable features of what America calls "scientific management."

General Works Organisations.—The centralisation of work, with consequent grouping of similar machines, was considered to be the ideal engineering practice a few years ago, but the practice is now deservedly losing much of its favour, where the finished product contains a large number of detail parts. Its chief advantages can only be obtained by the formation of a centralised system of arranging the work on every machine independently of the various foremen. A large workshop should be an aggregation of small shops or sections, in the author's opinion, which can preferably be separated by some form of barrier, but it is essential they should be under a centralised progress system and centralised management. In this way, taking as an example a works producing petrol engines, there would be a crank shaft section, a cylinder section, a crank case section, and each would have its own complete quota of necessary machine tools, and its own bonus on output. To start upon a new type of engine, under these conditions, would not be a great problem, as every part on a new design is more or less similar to its predecessors.

There is yet a very much wider field for the semi-specialised manufacturing machine tool. As an example, there is not a lathe for sale which it is not possible radically to alter and improve, which is designed solely for motor car or aeroplane engine crank shafts. It still seems necessary for every concern to design and build a large proportion of its own manufacturing machine tools to maintain its progress and commercial supremacy. The professional machine tool maker can use very few specialised tools in his manufacturing, and a batch of twelve similar machines is as near as he usually gets to repetition work. It is, however, rather a hopeful sign that many machine tool firms are now specialising in particular lines, and not making everything that offers itself to them, as in the past.

Degrees of Use of Special Tools.—It is a debatable point to know to what extent components should be "jigged and tooled" according to the quantity required "off." There are several firms in this country who lay out and manufacture a complete set of tools for so small a number of pieces as five. This is a small quantity, and depends upon the organisation and manufacturing methods employed by the concerns. In the author's opinion, it is more a question of time that should decide the matter; that is to say, if the component can be machined by special tools and unskilled labour in very much less time than with standard fixings, the special tools should certainly be made even if the total cost, including the took making, comes higher than the mathematically calculated saving. There will be other things to consider, for instance, the time occupied by the shop administration in rigging up temporary tools, the chances of error and scrap, or the possibility of a repeat order. Furthermore, the special tools themselves will have a certain plant value.

Formulæ of Output to Pay for Tools.—Some formulæ, and the mode of procedure, in connection with the foregoing remarks, may be of interest, and are given below:

1. Lay out operations for the piece, using existing tools.
2. Lay out operations for the piece, using special tools.
3. Ascertain definitely what is the total number of parts required.
4. Estimate the cost of machining, using existing tools.
5. Estimate the cost of the special tools required.
6. Estimate the cost of machining with the special tools. In doing this, points peculiar to the establishment should be observed, and the various fixed charges

* Paper read before the Institution of Mechanical Engineers on Friday, March 21, 1919.

put on each. This is important, as the tool-room charge and the manufacturing working cost load is usually different. It should also be borne in mind that with special tools, cheaper labour can be used.

If E equals cost of the component, using existing tackle.

If S equals cost of the component, using special tools.

If T equals cost of the special tools.

If N equals number of parts to be made.

Then, excluding items of expediency, the least number of components required to cover the cost of the tools will be given by :—

$$N = \frac{19\,T}{20\,(E - S)}$$

works at present is to make special tools for quantities of at least 25 components, as the advantages in practice outweight the difference in cost.

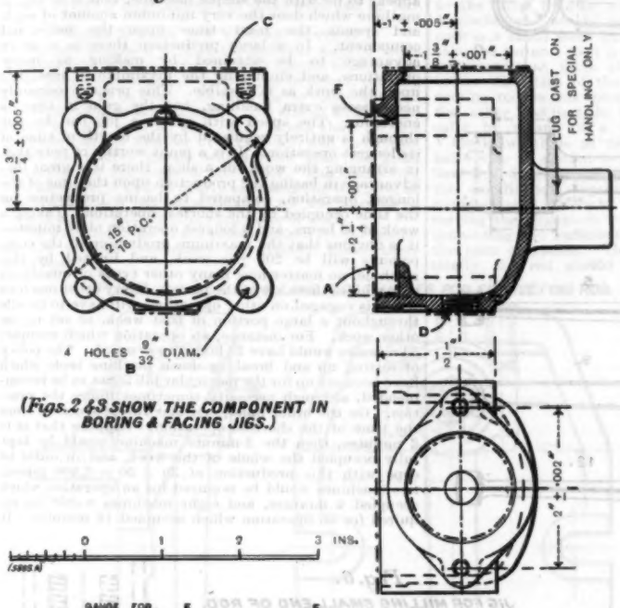
Financial Aspects of Manufacturing Improvements.—There is another item worth notice, which applies only to a competent which is in continuous manufacture. Let it be supposed that by the methods already in use, each piece costs 100*d.* to manufacture, and that by designing certain tools it were possible to reduce the cost to 95*d.* What amount would be justified in plant expenditure in order to effect this saving? The gain obviously would be 5 per cent. (apart from a possible increase in selling value and decrease in percentage of scrap).

If the component is to be manufactured indefinitely, the value of the extra plant expenditure allowable may be taken at 50*d.* per component per annum, since the increase of capital to produce 5*d.* extra dividend would have been 100*d.* This, therefore, leaves a margin of 2½ per cent., and if the output had been 100 per week only, this would give a safe expenditure of 1,080*l.*

Where a component would last, say, six months only, the balance between the saving and the total output must be reckoned. Following the previous example, under the given output of 100 per week and the saving of 5*d.* per component, the expenditure thus allowed to improve methods would have been only 54*l.*, but since a lower cost of manufacture implies a proportional reduction in the time occupied, a further 5 per cent. of the 26 weeks' output value may be added for this, giving a total of 108*l.*

This is the manner in which the plant cost of jigs and tools should be considered, but there is no special machine tool which is likely to be designed for cost reduction purposes (and this is a most important consideration), which would not be easily adaptable to alterations in the design of components. Take the matter of tool expenditure in an even larger aspect. If a car or aeroplane could be produced to sell at 500*l.* by using existing methods, then possibly 550*l.* could be obtained for the better quality that would result if special machine tools were used and interchangeability obtained; and certainly the manufacturing cost could be reduced by 50*l.*

Fig. 1. COMPONENT OF AERO-ENGINE.



(Figs. 2 & 3 SHOW THE COMPONENT IN BORING & FACING JIGS.)

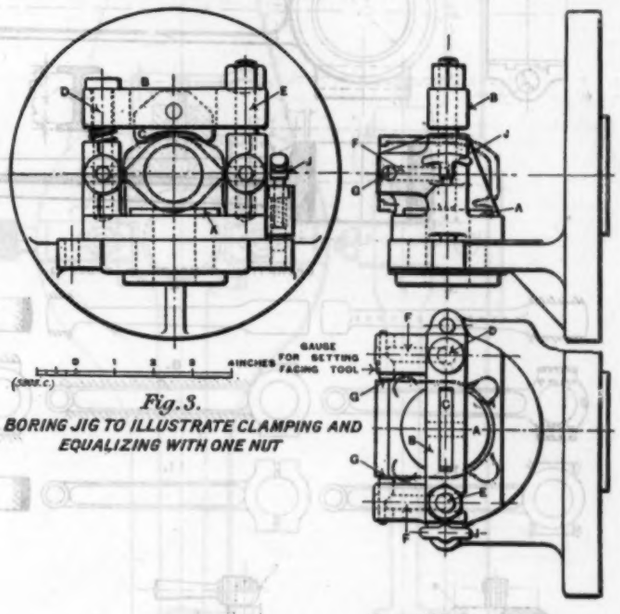


Fig. 3.
BORING JIG TO ILLUSTRATE CLAMPING AND EQUALIZING WITH ONE NUT

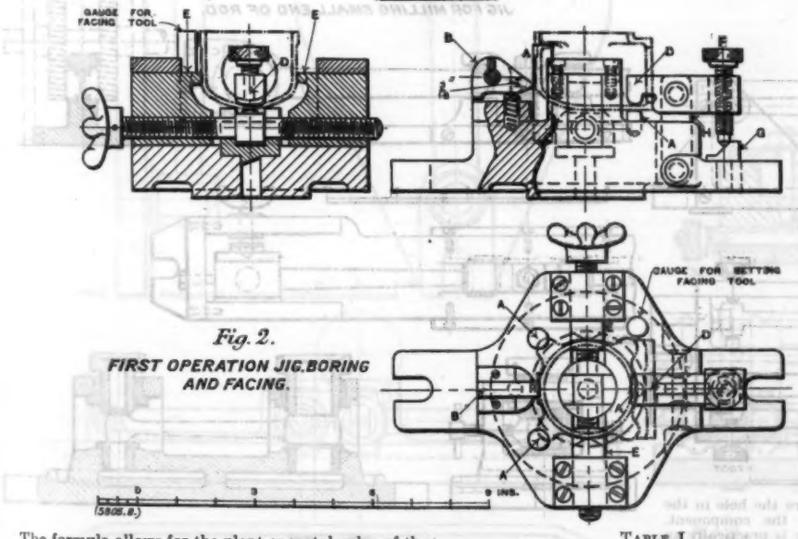


Fig. 2.
FIRST OPERATION JIG. BORING AND FACING.

The formula allows for the plant or metal value of the tools (assuming they are never used again for the component), as 5 per cent. of the original cost, which is perhaps rather high.

Similarly, the maximum that may be spent on special tools for "N" components is given by :—

$$T = \frac{20\,N\,(E - S)}{19}.$$

To give an idea how the formulæ work out, they have been applied to a small aero engine component, Fig. 1, above. There is comparatively little machining upon it, and assuming that the casting is to be tooled without special tools, the operations will be as in Table I. To grip the work in a chuck, it will be necessary to cast a small spigot on it for holding purposes.

It is to be noted that the slowest operation is that of setting the angle plate to the correct dimension, 1 in. ± 0·005 in., but if there were five or six pieces to run through consecutively, a considerable saving in time would result, as the machine could remain set up.

Employing jigs, but no special reamers or other tools, the job would work out as in Table II on this page.

The usual practice in most of the English automobile

TABLE I.

Operation.	Time Allowed.	Rate.	Cost.
	hr. min.	per hour. s. d.	s. d.
1. Preliminary marking off ..	0 10	1 6	0 3
2. Bore and face (hold in chuck by special spigot) (A) ..	0 30	1 2	0 7
3. Mark out and drill four holes in front (B)	1 0	1 2	1 2
4. Set up on an angle plate to bore and face end (C) ..	2 0	1 2	2 4
5. Mark out for drilling ¼-in. holes on face (C)	0 30	1 6	0 9
6. Drill and tap ¼-in. holes on face (C)	0 30	1 2	0 7
7. Drill face and tap bottom hole (D)	0 20	1 6	0 6
8. Cut off turning spigot ..	0 17	1 2	0 4
9. Hand finish where spigot is cut off	0 10	1 0	0 2
10. File notch (F)	0 20	1 6	0 6
	5 47		7 2

TABLE II.

Operation.	Jigs and Gauges.	Cost.	Time and Rate.	Cost of Labour.
		£ s.		d.
1 Set in jig ..	Jig	10 0	10 min. at 8*d.*	1·33
Bore and face at (A)	Combined depth and plug gauge ..	0 15		
2 Set in jig ..	Jig	8 10	10 min. at 8*d.*	1·33
Bore and face at (C). Revolve jig and face at (D)	Plug gauge ..	0 10		
3 Drill all holes. Tap holes where required ..	Drill jig ..	12 0	15 min. at 6*d.*	1·5
4 Mill slot (F)..	Mill jig ..	4 0	2 min. at 6*d.*	0·2
	Total cost of tools ..	35 15	Machining cost ..	4·36

From these two sets of figures we get :—

Cost of component for machining, using existing tackle ... E = 7*s.* 2*d.*

Cost of component for machining, using special tools and gauges .... S = 4·36*d.*

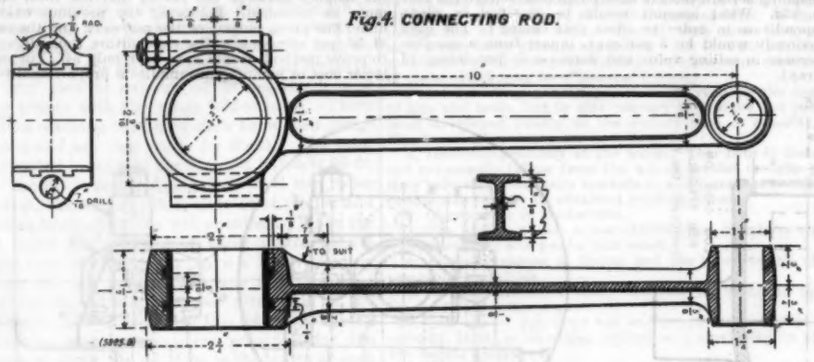
Cost of special tools ... T = 35*l.* 15*s.*

The number of components to cover the cost of tools is equal to :—

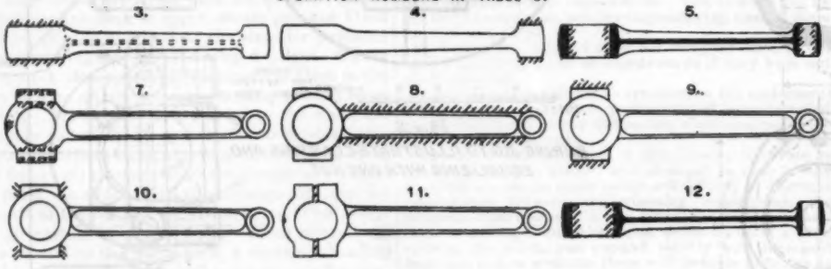
$$\frac{19 \times 35l.\ 15s.}{20\ (81 \cdot 64)} = 100.$$

at least. This gives a total gain of 100*l.* on every 500*l.*, or 20 per cent. If the original capital of the company were 500,000*l.*, then they would be quite justified in spending a further 15 per cent. of their original capital on special plant to attain this object—in this case, a sum of 75,000*l.* Unfortunately, the plant and engineering side of the question is not the only one to count, as there would have to be a guarantee that the works could be organised to make use of the special machines to the fullest extent.

Fig. 4. CONNECTING ROD.



OPERATION NUMBERS IN TABLE 3.



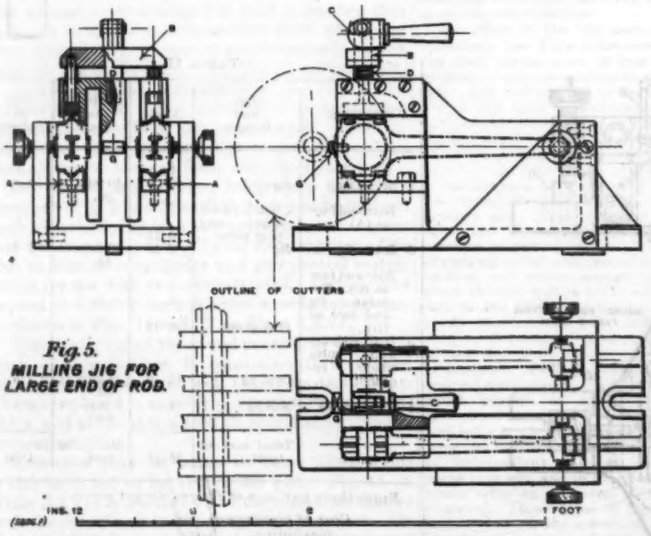


Fig. 5. MILLING JIG FOR LARGE END OF ROD.

Jigs for Aero-Engine Component.—It is now proposed to give a description of the tools for the small component previously mentioned, Fig. 1. The boring and facing jig is shown in Fig. 2, page 403. The machining which will be performed in this tool will be used in locating all the subsequent operations, and is therefore the most important. The work rests on three pegs A, two of which take support under the bolt bosses, and one at the back of the casting. To make certain that the bored hole will be central with the outside, an equaliser E is employed, which consists of jaws moved by a right and left hand screw. These will grip the work and be sufficient to drive the component against the cut. To make certain that the work is set down properly upon the pegs, a special stop B is employed, of which the point of contact is $\frac{1}{16}$-in. below the centre line of its pin, and the more horizontal pressure there is against it, the more the component will be thrust on to the seating pegs. The clamp D fills a double purpose by the action of one set screw F. When this is turned round, it moves down the taper of the hardened bevel block G, and the clamp being held pivotally upon a link H, it presses both forward and downwards.

With unskilled and female labour it is worth almost any expense in a tool to save the tightening of several screws in setting work. If a job can be put in a jig and all the necessary locations properly seated, and clamping achieved by one action, the tool is quite "fool-proof." To show how multiplicity of clamping operations can be avoided, the jig, Fig. 3, page 403, is more interesting, and although it is complex, the work cannot be put in wrongly. The piece is located from the previous operation on spigot A, and it is now necessary to face and bore the hole in the top of the component. The jig is practically an angle-plate set positively in two directions, but the component must yet be located in such a way that the machining is square with the general form of the casting. The clamp B with a floating fork C is hinged round the stud D, and clamped by the nut on stud E. On studs D and E is a bevelled recess which slides on longitudinal studs F, and these in turn are bevelled against the equalising studs. When the nut is tightened, the hardened pins slide against one another and the work is equalised and clamped at one operation. When the front face has been bored and machined, the whole fixture is indexed round 180 deg. by means of index pin J, and the back is then faced and drilled without disturbing the component.

Multiple-operation Machines.—The multiple-operation machine is usually very expensive in first cost. It also requires highly skilled setting-up, and is often dependent on one particular man, who has specialised the machine. The cost of the set-up, and the wear and tear of the tools, will be expensive. Multiple operations lengthen out the actual time of handling per piece, and great care and judgment must be given to the chucking of the work. Usually when several operations have to be performed upon a particular component, there is very little space left for gripping, as the area to be tooled is large, and necessitates a very firm grip being taken on a small area, thereby very likely seriously deforming the work. It is sometimes possible to have two multiple machines worked by one operator, and there is a certainty of accuracy between the hole and periphery of the job, which cannot be otherwise guaranteed.

Single-operation Machines.—The chief advantages appear to lie with the simple machine, that is to say, a machine which does the very minimum amount of work and spends the least time upon the individual component. In a large production there is a great advantage to be obtained by making as many operations, and employing the maximum of machines upon the work as is possible. This practice certainly necessitates extra handling, but the gain in time is enormous. The speed with which a job can be put through is entirely regulated by the length of time of its longest operation. It is a point worthy of note that in arranging the work for a shop, there is a great disadvantage in basing the production upon the time of the longest operation, compared to basing production on the time occupied by the shortest operation. Taking a week of 50 hours, and a longest operation of 15 minutes, it is obvious that the maximum production of the components will be 200 per week, and limited by this machine, no matter how many other types or quantities of machines there are in the place. Every other machine which is engaged on other operations will have to be idle throughout a large portion of that week, or set up on other work. For instance, an operation which occupies 7½ minutes would have 25 hours unoccupied. The policy of setting up and breaking down machine tools which have been set up for the particular job is not to be recommended, although necessity sometimes forces the practice. On the other hand, consider the production from the time of the shortest operation. Suppose that it is 2 minutes, then the 2-minute machine would be kept fully occupied the whole of the week, and in order to cope with this production of $30 \times 50 = 1{,}500$ pieces, two machines would be required for an operation which occupied 4 minutes, and eight machines would be required for an operation which occupied 16 minutes. It is therefore very much to the advantage of the work in every way to be able to work upon the basis of one machine for the shortest operation, and balance up from that; there are then no idle machines. It will be further observed from the foregoing remarks that if the 16-minute operation can be split up into two parts which occupy 10 minutes each, there would be a very decided gain in production, and it would be far more advantageous than installing two machines of the 16-minute operation, because it is reasonable to assume

Fig. 6. JIG FOR MILLING SMALL END OF ROD.

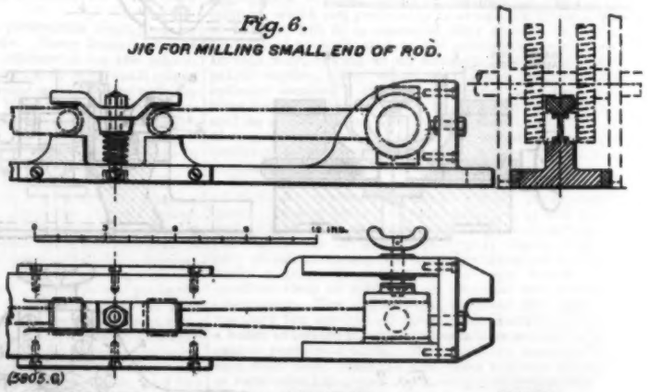
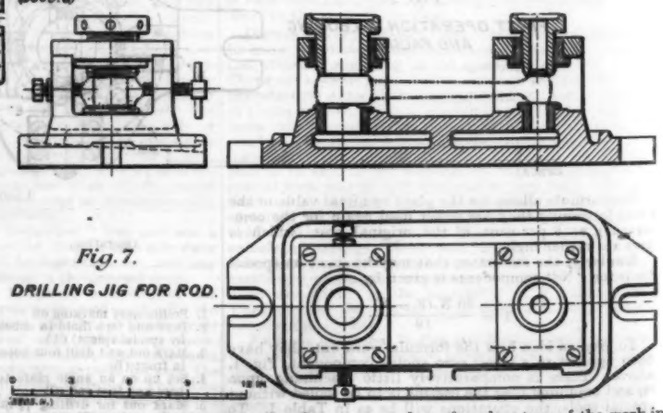


Fig. 7. DRILLING JIG FOR ROD.



that the 10-minute operation will be only five-eighths as complicated. The simpler and shorter the operation, the cheaper is the labour which can be used, and the machine will require very much less setting up, and very much less skilled attention. Output therefore depends upon the time of the longest operation, and if this can be reduced, there will be an increase of production.

It will be found in the majority of cases that simple operations are very readily adaptable to existing machine tools and plant, which are often widely different in their original purpose from that required.

In a very large subdivision of operations, consecutive gauging becomes a necessary item, and this should be done immediately after every operation. It is essential that every piece should be gauged as it comes off the machines, even if it has to be moved to a special viewing room, as any error is then found immediately after it is made, before a large amount of scrap work can be produced.

Tools Scheme for Various Outputs.

It is now proposed to show the different ways in which a component may be equipped with special tools, at the same time describing the various jigs in detail, showing the methods to be used. An auto engine connecting rod has been taken as the example. The author would much prefer to have used an aero engine crank shaft for this purpose, but the number of operations, and the consequent descriptive matter would have been too great altogether for the scope of the paper. The connecting rod, however, is now of nearly as standardised a form as the crank shaft, but unfortunately for the purpose in view it is a very straightforward piece of work.

The considerations of the tools required for the manufacture of this component are divided under three headings.

Fig. 8. JIG FOR DRILLING BOLT-HOLES FOR CONNECTING ROD.

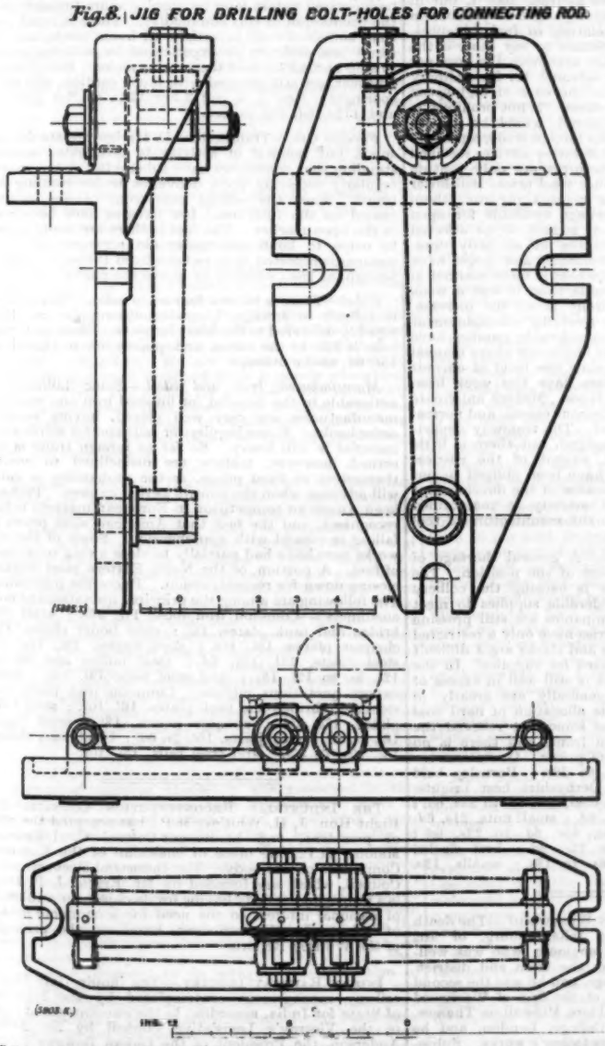


Fig. 9. JIG FOR MILLING SIDES OF ROD ON BOLT-HOLE BOSSES

Scheme 1.—A lay-out suitable for a contract of, say, 500 to 2,500 connecting rods.

Scheme 2.—A lay-out suitable for a contract of, say, 2,500 to 50,000 connecting rods.

Scheme 3.—A lay-out suitable for the permanent manufacture of the piece, or rather, a practically unlimited output in rate of manufacture and total quantity.

In each case the output will be estimated on the basis of the shortest operation, to obtain the most economical results, as mentioned previously in the paper.

The connecting rod and cap which are manufactured throughout together, are illustrated in Fig. 4, and produced from one stamping, so that the connecting rod and cap are made together when forging. The manufacturing operations in the smallest basis of production are as in the lay-out under Fig. 4, Table III, page 406.

Jig for Milling Large End of Connecting Rod (Fig. 5).—There are two connecting rods placed in the jig at once, and a gang of four straddle mills are advanced across the work. The components are held at the bottom in fixed V-blocks, AA: and both are gripped together by a clamp B, which is given a wide range of movement by a cam C, pivoted on fixed stud D. The clamping action is transmitted to the work by two sliding V-blocks, and at the top of each is a small steel ball, to take the thrust. As it is most important that there should be no distortion of the connecting rods in this operation, the other end is held vertically by means of a fixed V-block, which is as near a knife-edge in section as practicable, and a set-screw pushes the small boss against a rounded stud, thereby preserving the alignment of the connecting rod sufficient for the next operation. Theoretically, the rod should have been "equalised" at this end, but, if there is a moderate machining allowance for facing, it becomes an unnecessary refinement.

This operation is likely to give trouble if the cutters are not of a reasonable stiffness, and should there happen to be more metal to remove from one face of the connecting rod than the other, the cutter is likely to spring, owing to its large diameter. To get the best results, there should be a close spacing of the cutter teeth—the opposite of the modern practice of giving cutters the fewest possible teeth. The reason is that the metal to be operated on is likely to prove hard. If there is a fairly large feed (say, 1 in. per minute) and wide spacing, there is a substantial knock, due to the large shoulder of metal which will have fed up while the cutter tooth space has been passing. This knock is transmitted throughout the milling machine, and causes the cutter teeth rapidly to become dull, as well as producing a poor

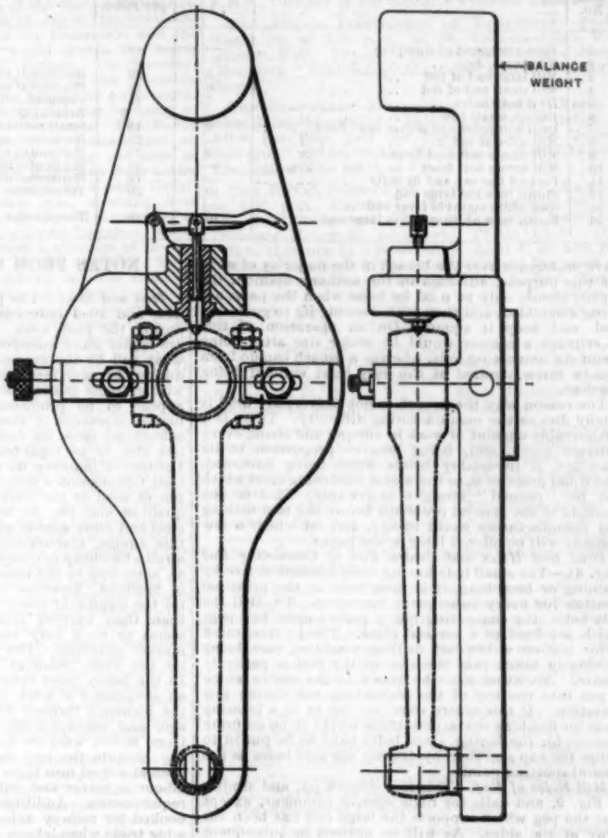
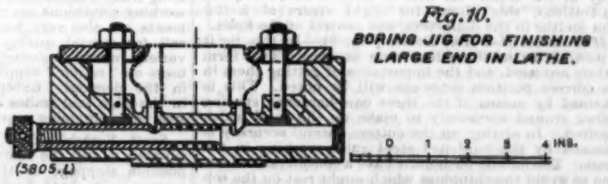


Fig. 10. BORING JIG FOR FINISHING LARGE END IN LATHE.



finish on the work. The setting gauge G is made of hardened steel, and is about $\frac{11}{1000}$ less in width than the finished work. In setting up, a feeler is used $\frac{11}{1000}$ in. thick, and the cutters thereby spaced equally on each side of the gauge.

Milling the Small End of Connecting Rod (Fig. 6).—In all milling jigs it is one of the chief aims of the designer to make the height as small as possible, to prevent vibration and obtain stiffness. The rods are clamped at the large end against one of the machined faces and as longitudinal accuracy is not yet required, pegs are a sufficient support. The part where the cut has to be supported is clamped to a flat or slightly dished plate, and tightening one bolt is sufficient to hold two rods without distortion. Note that the direction of the pressure from the cut must be downwards on to the solid plate, and not against the clamps.

Rough Drill both Ends of Connecting Rod (Fig. 7).—This jig is of "box" form, and as the walls of metal around the small hole are not to be machined outside, and also are comparatively small, the location is taken from a screwed bush, which seats conically upon the small end, thereby obtaining concentricity. The bosses of the connecting rod rest upon hardened bushes, the holes of which are larger than the drill-guide bushes, to clear the drills when breaking through the work. The bush under the large end has three relieved feet to keep the face clear of the chippings. The bushes are formed to make cups for the lubricant, and the whole base of the jig forms itself naturally into channels for carrying away the cutting solution. The bushes of the screw-down type are far from being ideal construction, as it is practically impossible to say that a threaded bush is perfectly square or without play. Bushes with a spiral recess are now largely used instead.

Broaching the Small Hole.—The small hole having been drilled about 12 to 15 thousandths smaller than the finished size, it is possible to broach out this amount in one "pull through," on a modern broaching machine. At the present date, however, the reamer still seems to

Table III.—Scheme for Small Production.

Maximum output = 6 per hour = 300 per week.

Operation No.	Description of Operation.	Fig. No. of Jig.	Time Required Minutes per Piece.	Type of Machine.	No. of Machines.	Labour Cost per Piece.
1	Heat treatment of stamping	—	—	—	—	—
2	File burrs, &c.	—	—	—	—	—
3	Mill large end of rod	5	20	Horizontal miller	2	3·3
4	Mill small end of rod	6	12	Horizontal miller	1	0·2
5	Drill both holes	7	16	2-spindle drilling	2	2·5
6	Broach small end	—	½	Broaching	1	0·1
7	Drill bolt holes and centre end of rod	8	15	Small radial drill	2	2·5
8	Mill sides of rod	—	25	Horizontal miller	2	4·2
9	Mill across bolt-hole bosses	9	15	Horizontal miller	2	2·5
10	Mill across bolt faces	—	12	Horizontal miller	1	1·8
11	Part off the cap and fit bolts	—	12	Horizontal miller	1	1·8
12	Finish bore the large end	10	20	Turret lathe	2	3·3
13	Run white metal in large end	—	—	—	—	—
14	Finish bore white metal in large end	10	10	Turret lathe	1	1·7

have preference over the broach in the majority of work for this purpose, although in the author's opinion, the former should only be used by hand when the parts are being assembled, and then with a strong jig to guide the tool, and keep it square. On an operation of this description a reamer would be under size after doing about six connecting rods, whereas a broach can do from two to three hundred at the very least without being touched.

The reason why the broach is not universally used is chiefly due to the manufacturing difficulty. There is a considerable amount of work in cutting and sizing every separate tooth, and, being long in proportion to its diameter, it invariably bends when being hardened. The usual practice is to use a case-hardening steel which can be "peaned" straight afterwards. This is one example of the general problems before the tool-making and manufacturing world to-day, and on which a few remarks will be offered later in the paper.

Drill Bolt Holes and Centre End of Connecting Rod (Fig. 8).—The small hole having been finished to size by reaming or broaching, it is then used as the principal location for every subsequent operation. To drill the bolt holes, the connecting rod is placed upon two pegs which are fixed to a vertical plate. The jig illustrated is for use on a box-bed drilling machine, care being previously taken that the side of the bed is perfectly square. Attention must be drawn to the centre which is put into the top of the connecting rod during this operation. If this centre were not put in as a locating point for finishing operations, there would be no accurate location for the boring, since bolts have to be put in to secure the cap and thereby destroy the side holes as the natural spotting points.

Mill Sides of Rod.—This is a duplex jig, and similar to Fig. 9, and calls for little special comment, except that the peg which supports the large end has been cut away at the sides. As will be noticed in subsequent illustrations, this allows for slight errors of a few thou andths in the diameters, and centres of the holes.

Mill Across Bolt Hole Bosses (Fig. 9).—In this jig it is possible to machine four rods at once. Two form cutters are used, and the importance of getting them in the correct position sideways will be noted. This is obtained by means of the three case-hardened spacing bushes ground accurately to make up the total width required. In setting up the cutters, lateral accuracy is obtained by the hardened steel guide working in the recess. The middle bush must have a considerable clearance to avoid the chippings which might rest on the top face of the strip.

Milling Bolt Faces.—It has not been considered necessary to show a drawing of this jig, as it will be practically the same in construction as Fig. 9, except that side facing cutters are used, and the cutters will operate at right angles to the direction in that case.

Parting Off the Cap.—This is done in a jig, and the cap removed by means of a ⅛-in. circular saw. The disk method of positioning the cutter laterally is again used, and location taken from the small hole.

Finish Bore the Large End (Fig. 10).—The cap having been bolted to the connecting rod after the sawing operation, the rod is ready for finish boring. To do this (since the large hole is no longer round) the location is obtained from the centred hole. The boring jig shown is for use in a lathe, and the spigot fits in a recess in the face plate. The equalising clamp is a construction detail worthy of notice, as it is placed here to make a support against the pressure of the cutting tools. If no stops are used, there is danger of twisting the connecting rod, and throwing the finished hole out of alignment with the small hole; and accuracy in this respect is most essential. When the rod is machined in a centre lathe, the work will require turning round and re-setting. The rod is then white metalled, and afterwards only requires a finish boring operation on the soft metal. The boring jig is practically identical with the one already illustrated in Fig. 10.

(To be continued.)

Launch of H.M.S. "Stonehenge."—Messrs. Palmer's Shipbuilding and Iron Company, Limited, launched from their Jarrow shipyard, on Wednesday, the 19th inst., the torpedo-boat destroyer Stonehenge, built for the British Navy. The Stonehenge is the forty-seventh torpedo-boat destroyer built by the firm for H.M. Government, and the one hundred and third warship they had launched.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Iron and Steel.—The position of the South Yorkshire iron and steel industries has undergone little change during the past week. Inquiries from foreign buyers are rather more numerous, but as makers do not know what will be the extent of the upward trend of prices during the next few months, they are compelled to act with extreme caution, and in many cases to refuse what appear to be promising connections. There will be further advances in steel prices as from May 1, but in calculating rates for future delivery, cost of production has also to be regarded as relating to fuel advances. Leaders of industry do not hesitate to say that, if the Coal Commission's proposals are accepted, the cost per ton of steel at the works will advance 8*s.* for ordinary qualities and 18*s.* to 1*l.* 2*s.* in the case of high-speed steel and other special quality steels. If not prohibitive, this advice, manufacturers contend, would be a very serious handicap in competing for foreign trade, especially as, according to the latest authoritative advices received in Sheffield, American manufacturers are only waiting for the signing of peace to reduce steel prices still lower than their current level. As regards pig-iron, there seems to be a very small tonnage available for open market purchase. The position is said to be affected by the likely removal of subsidies at an early date. In the heavy steel branches, foundries and forges have an abundance of work, but slackness is more marked in the Siemen's furnace departments than it was a week ago, and unemployment generally is on the increase. Over 20,000 workers are now receiving unemployment pay, despite the fact that a considerable number have been absorbed into those lighter industries where manual labour is scarce and output below the level of current requirements. Additional orders have this week been booked for railway axles and tyres. Makers anticipate a big trade when labour unsettlement ceases, and normal working conditions are restored. The tramway departments are also very busily engaged, but there is little call for special quality steel, except of the rustless variety, where manufacturers have been obliged to put users on "ration" supplies, because of the development in the demand. Exceptional activity is maintained in the edge tool trades and in the manufacture of tool steel and gardening requisites.

South Yorkshire Coal Trade.—A general shortage of supplies is still the main feature of the position. The possible stoppage at the pits is causing the colliery companies to keep back considerable supplies to meet their own needs. Railway companies are still pressing for best steam hards, but collieries have only a restricted output to offer. Cobbles, nuts and slacks are a difficult market, contractors pressing hard for supplies. In the house coal section, the demand is still well in excess of the output, and merchants generally are greatly in arrears with orders, though the allocation of hard coal for household consumption has somewhat relieved the strain. Cokes maintain a firm front, and there is no difficulty in obtaining maximum prices. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

The late Mr. Charles John Westwood.—The death has recently taken place at Johannesburg, of Mr. Charles John Westwood, civil engineer, who was well-known and highly respected in the town and district. The deceased was 65 years of age, and he was the second son of Mr. Joseph Westwood, of the firm of Westwood and Baillie, ship and bridge builders, Millwall-on-Thames. He was educated at King's College, London, and he served his apprenticeship at his father's works. Subsequently he became a partner in the firm of Joseph Westwood and Co., bridge builders, Millwall, and he founded the firm of Westwood and Winby, and secured the contract for the construction of the Selati Railway. He first visited South Africa in 1893, and, later, he founded the firm of C. J. Westwood and Co. Among other engineering works the firm carried out were the construction of the Newport, Godshill and St. Lawrence Railway, and the Greenwich and Catford tramways. He retired in 1909, and took up his residence at Krugersdorp. He is survived by a widow and three grown-up sons.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

Middlesbrough, Wednesday.

The Cleveland Iron Trade.—A quieter feeling is noticeable in the Cleveland iron market, and many traders take anything but a cheerful view of the outlook. The iron in chief demand is foundry quality, production of which falls vastly below needs. So much so that consumers are stated to be receiving little more than 25 per cent. of their requirements, and they are compelled to take up large quantities of forge pig-iron, which is plentiful, to mix as extensively as possible with the superior quality. As the maximum price is paid for both foundry and forge iron—No. 3 and No. 4 forge being the same price—there is little inducement to make any effort to improve the quality of production. Cost of output is steadily increasing, and it is generally admitted that on the withdrawal of the subsidy to makers at the end of next month, prices will have to be advanced substantially. A rather better supply of trucks has slightly improved facilities for home distribution, but they are still far from what could be desired. Export trade is practically at a standstill. In addition to the very great difficulty in obtaining the class of iron needed for export, arrangements of credit can hardly be made, and international rates of exchange are such as check attempts at foreign business. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry, and No. 4 forge all stand at 95*s.*, and No. 1 is 99*s.*; whilst for export, No. 3 and the lower qualities are 145*s.* and No. 1 is 150*s.*

Hematite Iron.—There is now almost an abundant supply of East Coast hematite, and make is likely to be increased before long by turning more furnaces on to the production of this commodity. There is much more than sufficient iron to satisfy all home needs, and as a result less difficulty is experienced in securing permits to ship abroad some of the surplus make. Such licences, however, are still granted with much caution, and rather sparingly. Nos. 1, 2 and 3 are 122*s.* 6*d.* for home use and 172*s.* 6*d.* for export.

Foreign Ore.—Transactions in foreign ore are few and small, but renewal of activity is anticipated notwithstanding that consumers have substantial stocks and are regularly receiving good deliveries under running contracts. Since the official chartering of ore steamers ceased on the 15th inst., few fixtures have been made in the open market. The fact is there are many cargoes to come to hand yet under old arrangements. One steamer is reported to have been fixed Bilbao to Middlesbrough, at 20*s.*, which is 3*s.* above the parity.

Coke.—There is no new feature in coke. New business is difficult to arrange, but adequate supplies are being steadily delivered to the blast furnaces. Medium furnace coke is 33*s.* at the ovens, and quality low in phosphorus 35*s.* 6*d.* at the ovens.

Manufactured Iron and Steel.—Some falling-off is noticeable in the demand for finished iron and steel, but manufacturers are very well placed, having excellent order books. Home inquiry for rails and for shipbuilding material is still heavy. So far as foreign trade is concerned, however, makers are disinclined to commit themselves at fixed prices, as the probability is values will advance when the control period expires. Probable keen American competition in European markets is fully recognised, and the fact that American steel prices are falling is viewed with apprehension. Some of the steel works here have had partially to close owing to shortage of fuel. A portion of the North-Eastern steel works is closing down for reconstruction. Prices are maintained. The following are among the principal quotations to home customers:—Common iron bars, 17*l.* 15*s.*; steel ship, bridge and tank plates, 14*l.*; steel boiler plates, 15*l.*; chequer plates, 15*l.* 10*s.*; steel angles, 13*l.* 12*s.* 6*d.*; steel joists, 13*l.* 12*s.* 6*d.*; steel billets and blooms, 12*l.* 5*s.* to 12*l.* 15*s.*; and steel rails, 13*l.* 10*s.*; whilst export quotations include: Common iron bars, 20*l.*; steel ship, bridge and tank plates, 16*l.* 10*s.*; steel boiler plates, 17*l.* 10*s.*; chequer plates, 18*l.*; steel angles, 16*l.* 2*s.* 6*d.*; steel joists, 16*l.* 2*s.* 6*d.*; billets and blooms, 13*l.* 10*s.* to 15*l.*; and steel rails, 15*l.* 10*s.*

The Industrial Reconstruction Council.—The Right Hon. J. H. Whitley, M.P., has accepted the office of president, and Lieutenant-Colonel C. L'Estrange Malone, M.P., the office of chairman of the Executive Committee of this body. The Industrial Reconstruction Council, which was founded by Mr. Ernest J. P. Benn, is a propagandist body having for its object the awakening of national interest to the need for a complete system of industrial self-government, based on the principles of the Whitley Report.

Indian Railway Inquiry.—The inquiry into Indian railway management contemplated by the Secretary of State for India, according to the announcement made in the Viceroy's Legislative Council by Sir Arthur Anderson, the President of the Indian Railway Board, will evidently be an important and comprehensive one. It is to deal primarily with what are known as "company" lines, namely, the lines owned by the State but managed by companies having their headquarters in London. The inquiry will investigate the desirability or otherwise on administrative and financial grounds of modifying that system of management by absorption of "company" lines into one or other of the State-managed lines, or by making them over to companies domiciled in India, or of converting them into State-managed lines.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—Despite the prevalent uneasiness regarding the immediate future of the industry, steel-makers have little cause for complaint. It is true, no doubt, that in the meantime large contracts are not so numerous as they were in former years, nevertheless the output is limited perhaps only by the available labour. The shipbuilding yards and the general engineering establishments are very busy, making heavy demands upon the plate and rolling mills, ship and boiler plates and sections being much in request. While the bulk of the output is being requisitioned for home consumption, overseas buyers are daily becoming more clamorous for increased supplies of finished and semi-finished steel, and, even as things are, there is little fear but that manufacturers will make a strenuous endeavour to keep pace with these demands. With the rolling mills fully employed, and raw material coming in more freely, there is every prospect of a largely augmented output before very long, more especially if a sufficiency of labour is forthcoming to give the new three 8-hour shift system a good send off. This drastic change, added to the heavy cost of fuel, may mean an advance in the price of all classes of steel, but it is not advisable to make any definite pronouncement meantime.

Malleable Iron Trade.—The demand for malleable iron is one of the outstanding features of the iron and steel industry at the moment. Plants are fully occupied turning out a large volume of work which goes straight into the hands of the home consumer, export being left severely alone, until a better opportunity presents itself for consideration of the claims of overseas buyers. Prices will advance when the new working day comes into being, and in consequence of the expected change makers are running no risks, but are safeguarding themselves on every occasion. In all likelihood the advance will amount to something like 30*s.* per ton, thus making bar iron 21*l.* per ton f.o.b., Glasgow.

Scotch Pig-Iron.—The prevailing uncertainty is making matters in the pig-iron trade rather difficult, although a large volume of work is being put through, with all brands much in demand, hematite and foundry iron being so greatly in request that it is not always possible to keep supplies level with the demand. By doling out the production as sparingly as is compatible with the needs of the consumers, makers are just managing to keep the market moving. The supply of forge iron is eminently satisfactory.

LAND SURVEYING AND LEVELLING.—The Permanent Exhibition of Concrete Products at 143, Grosvenor-road, mentioned in the paragraph under the above title on page 319 *ante*, was arranged by the Concrete Utilities Bureau, and not by the Associated Portland Cement Company, as stated in error in the data supplied us for the said paragraph. We are asked to state that the collection has been arranged from a purely educational point of view, and fulfils its purpose most admirably. It is an excellent object lesson even to those who have a professional knowledge of reinforced concrete construction, and is well worth a visit both by professional men and their clients.

MESSRS. VICKERS, LIMITED.—At an extraordinary meeting of shareholders of Messrs. Vickers, Limited, held at the River Don Works, Sheffield, last Monday, and dealing more especially with the proposed amalgamation with the Metropolitan Carriage, Wagon and Finance Company, Mr. Douglas Vickers, M.P., the chairman, said it was his conviction, which was shared by everyone whom he had consulted on the subject, and by all those who had studied the engineering trade, especially the foreign trade, that English manufacturers had been greatly handicapped by working in too small units. This principle was not confined to the electrical and engineering trades. He instanced the American steel trust, with its enormous capital and with its output of steel, which before the war was greater than that of all England combined. Then there were the two great American electrical firms and the two large German electrical firms, one of which was stated by its general manager in 1916 to have no less than 20,000,000*l.* invested in its business. These firms were on a scale and commanded reserves absolutely unapproached in this country. It was obvious that organisations such as these had a power of initiation and of following a continuous policy quite impossible for a large number of firms working individually, even if their total output was the same. It was also obvious that notable economies in selling could be realised, especially abroad, by employing one combined agency in each place instead of a large number of smaller ones. He compared their own firm with those large firms which to a great extent were the result of combinations themselves, and stated that the comparison was yet inappropriate to this extent—that what they proposed to do was not the formation of anything in the nature of a trust—a term which was somewhat unpopular among them—but was in the main a combination of various allied manufacturing businesses, which were not the same, but which supplemented each other, which would use each other's products and form a complete organisation capable of producing within itself practically all the elements necessary for the largest electrical engineering and transportation undertakings. They therefore thought that they were offering no menace to the public. They asked for no monopoly, and the advantage that they gained would be secured by economy of production, due to an assured market for their products, by economy in selling, and finally by their strong finance, and by the great power and influence which their outstanding position would give them.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—Operators on the Cardiff coal market have again had a difficult time during the past week. Irregular stoppages have been more prevalent than ever, and business has been rendered almost impossible. A large percentage of the miners refused to comply with the instruction of the Mining Federation that they should continue work on day-to-day contracts pending the final conference of the Federation and the decision as to whether they would accept the terms recommended in the Sankey Report. On Monday, practically the whole of the miners in the Rhondda Valley, numbering about 20,000, refused to go to work, as a protest against their leaders for not refusing to accept anything but their full demands. The South Wales Miners' Federation Executive Council met on Tuesday and passed a resolution urging the men to return to work, but their request was taken little notice of. In fact, including the stoppage at Messrs. Guest, Keen and Nettlefolds' Dowlais pits, affecting over 5,000 men, as the result of a dispute, and a stoppage at the Clydach Vale pits of the Cambrian Company, where about 4,000 men are out, through a shortage of timber, nearly 30,000 men were idle in the coalfield. These stoppages have had a substantially adverse effect on outputs, and with the Admiralty and inland consumers claiming a priority on all outputs there was very little coal left for general export. At the same time, the collieries continue to keep a large percentage of their outputs for their own use in the event of a stoppage. The only cheerful aspect in the labour situation is the fact that the strike of boilermakers in the Bristol Channel, which has been in progress for the past nine weeks, has been brought to an end, the men having returned to work on Tuesday on jobs left when they came out at the old rates of pay. In the meantime, the Joint Committee of the employers and men are arranging a new price list for riveters, which is to be brought into operation when the old jobs are finished. The jobs in hand will take quite a month to complete. Arrivals of tonnage have not been so heavy of late, and as the ship-repairing work is got out of the way it is expected that any shortage in shipping will be made up by the availability of completed vessels. Large Cardiff coals were very scarce for export and bunker classes and best small steams were also hard to get, while the authorities were only releasing supplies in special cases. Inferior smalls steams and dry smalls remained plentiful. There was only a small demand for coke, and the export business was quiet, and makers have been obliged to ease down outputs. Patent fuel was in good demand, and manufacturers have sufficient orders to keep them going for some time. Pitwood arrivals were insufficient to meet the requirements of collieries, and in some cases temporary stoppages have had to be effected owing to a lack of timber.

The Newport Market.—Monmouthshire steam coals have been in good request, and outputs have been insufficient to meet the demand. The inland inquiry continued very pressing, and the authorities were keeping a very close hand on shipments. It was very difficult to get large coals released, and the same applied to best small steams though the cheaper descriptions were plentiful. There has been a substantial decrease in the tonnage in dock, and a number of tips have been rendered idle owing to an insufficient supply of coals.

Coal Trimmers and Night Work.—Last month the Bristol Channel coal trimmers and tippers put in a claim for a 20 per cent. increase in wages and for an 86-hours' week composed of ten day shifts of 8 hours each and a 6-hour shift on Saturdays. The employers have agreed to the 20 per cent. increase conditionally upon a satisfactory arrangement being arrived at in regard to hours. The employers have offered the men an 88-hours' week, made up of five day shifts and five night shifts, with a short shift on Saturdays. The shifts suggested by the men will make a complete 16 hour day, but the employers ask for a break between the shifts in order to effect a clearance of empty wagons, &c., and thereby prevent congestion, which would handicap loading operations. The men, on the other hand, desire to abolish night work altogether, and the matter is being further negotiated upon.

South Wales Dock Facilities.—A committee has recently had under consideration the general question of transport and dock facilities in Monmouthshire and South Wales, in view of the probability of increasing coal outputs. Representatives of the dock and railway companies were present and the committee have decided to hear evidence and submit recommendations to the Coal Controller and the Railway Executive. This news is welcomed locally, as for some time past there have been complaints regarding a lack of tipping facilities at the Cardiff Docks especially.

Tin Plate Trade and Joint Selling Agency.—Manufacturers in the tin-plate trade are considering a proposal which in effect means the setting up of a joint selling agency run on co-operative principles, to sell the output direct from the works instead of through middlemen.

THE INCORPORATED MUNICIPAL ASSOCIATION.—The annual Convention of the Incorporated Municipal Association is to be held this year at Felixstowe, on June 17, 18 and 19. Owing to the limited accommodation available in Felixstowe—it being expected that there will be a large influx of ordinary visitors this year—the Convention is being restricted to members of the association. A preliminary programme will be issued to each member shortly.

NOTICES OF MEETINGS.

THE PHYSICAL SOCIETY OF LONDON.—Friday, March 28, at 5 p.m., at the Imperial College of Science, Imperial Institute-road, South Kensington, S.W. A discussion will take place on "Metrology in the Industries," to be introduced by Sir R. T. Glazebrook, C.B., F.R.S., Director of the National Physical Laboratory.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, March 28, at 7.30 p.m., at 39, Victoria-street, Westminster, S.W. Paper by Colonel the Master of Sempill (Member), "Wanderings Along the Future Commercial Route."

THE SURVEYORS' INSTITUTION.—Monday, March 31, when a paper, entitled "Building Contracts Before and After the War, and the Functions of the Quantity Surveyor," will be read by Mr. John W. Hurrell (Fellow). The chair will be taken at 5 p.m.

THE ROYAL SOCIETY OF ARTS.—Monday, March 31, at 4.30 p.m., Cantor Lecture: "Problems of Food and their Connection with our Economic Policy," by Professor Henry E. Armstrong, Ph.D., LL.D., D.Sc., F.R.S. (Lecture I). Wednesday, April 2, at 4.30 p.m., Ordinary Meeting: "The Cultivation and Preparation of Flax, and the Linen Industry," by William Norman Boase, C.B.E., Chairman of the Flax Committee for Scotland. Sir Frank Warner, K.B.E., President of the Textile Institute, will preside.

THE RONTGEN SOCIETY.—Tuesday, April 1, at 8.15 p.m., at the Royal Society of Arts, 18, John-street, Adelphi, a paper will be read by Mr. W. S. Lazarus-Barlow, M.D., F.R.C.P., on "Some Biological Effects produced by Small Quantities of Radium."

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Wednesday, April 2, at 8 p.m., at the Royal Society of Arts, John-street, Adelphi, W.C., when Mr. Carl Opperman will read a paper on "Electric Vehicles." A further meeting will also be held at the Chamber of Commerce Hall, New-street, Birmingham, on the following day, viz., Thursday, April 3, at 7.30 p.m., when Captain G. Smith-Clarke will read a paper entitled "Some Notes on Petrol Flow-meters and the Calibration of Carburettor Jets."

THE LIVERPOOL ENGINEERING SOCIETY.—Wednesday evening, April 2, at 8 p.m., at the Royal Institution, Colquitt-street, when a paper will be read by Mr. Bernard Rathmell, M.I.Mech.E., entitled "Refrigeration." The paper to be read on April 16 will be entitled, "Some Aspects and Developments of Mercantile Shipbuilding under War Conditions," by Professor T. B. Abell, R.C.N.C. (retired), M.I.N.A.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE, THE BIRMINGHAM METALLURGICAL SOCIETY, AND THE BRITISH FOUNDRYMEN'S ASSOCIATION (BIRMINGHAM BRANCH).—Thursday, April 3, at 7 p.m., Joint Meeting at the University, Edmund street, Birmingham. Paper by Dr. Hatfield, of Sheffield, on "General Consideration of the Mechanical Properties of Steels."

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, April 3, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. Lecture by Lieutenant-Colonel A. G. T. Cusins, R.E., on "The Development of Army Wireless During the War."

THE ROYAL SANITARY INSTITUTE.—Friday, April 4, at 7 p.m., at the Town Hall, St. Helens, when a discussion will take place on "The Elimination of Insanitary Areas," to be opened by Mr. F. E. Wynne, B.A., M.B., D.P.H. (Medical Officer of Health, Wigan). His Worship the Mayor, Mr. Alderman H. B. Bates, will welcome the members at 7 p.m. The chair will be taken by Professor A. Bostock Hill, M.D., M.Sc., D.P.H.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, April 4, at 5.30 p.m., a discussion will be delivered by Professor Frederic Harrison, D.C.L., D.Litt., LL.D. The subject will be "History of the City of Constantinople." Afternoon Lectures, at 3 p.m.: Tuesday, April 1, Professor A. Keith, M.D., LL.D., F.R.S., F.R.C.S., Fullerian Professor of Physiology, Royal Institution, on "British Ethnology—The People of Scotland" (Lecture III). Thursday, April 3, Professor Alexander Findlay, D.Sc., F.I.C., on "Colloidal Matter and its Properties" (Lecture I). Saturday, April 5, Professor Sir J. J. Thomson, O.M., LL.D., D.Sc., Pres.R.S., Professor of Natural philosophy, Royal Institution, on "Spectrum Analysis and its Application to Atomic Structure" (Lecture V).

THE INSTITUTION OF LOCOMOTIVE ENGINEERS: MANCHESTER CENTRE.—Friday, April 4, at 7 p.m., at College of Technology, Manchester, paper by Mr. Gass, on "Relation of Boiler Power to Cylinder Capacity." Saturday, April 12, at 2.30 p.m., at Caxton Hall, Westminster, London. Paper by Mr. P. C. Dewhurst, on "Steel Fire-boxes and Tubes in Locomotive Boilers."

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—Friday, April 4, at 11 a.m., in the Lecture Theatre of the Institution of Civil Engineers, Great George-street, Westminster, a Special Meeting will be held for the purpose of discussing the Housing Problem. The President of the Local Government Board (the Right Hon. C. Addison, M.D., M.P.) has promised to attend and deliver an address. This meeting will be followed at 2 p.m. by a Conference on the National Housing Scheme, at which the Director-General of Housing (Sir James Carmichael) will be present.

THE LONDON ASSOCIATION OF FOREMEN ENGINEERS.—Saturday, April 5, at 7 p.m., at Cannon Street Hotel, London, E.C. Paper on "The Science of Fine Measurements," by Mr. Vernon Williams.

H.M. SEAPLANE-CARRYING SHIP "ARGUS."

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(*For Description, see Page* 400.)

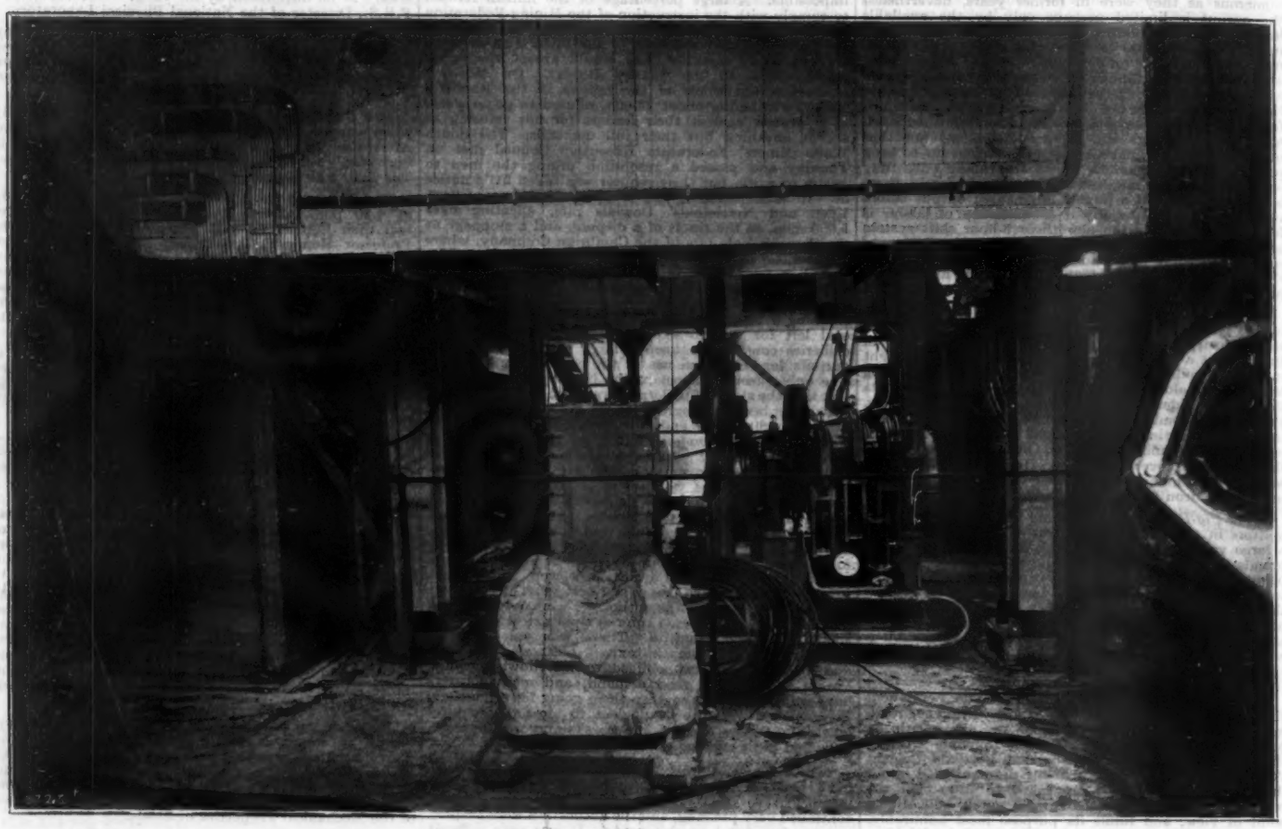

FIG. 16. MACHINERY FOR RAISING CHARTHOUSE TO FLYING DECK.

FIG. 17. GENERAL VIEW ON HANGAR DECK.

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

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With Four One-Page Plates of H.M. SEAPLANE-CARRYING SHIP "ARGUS."

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 407.

ENGINEERING.

FRIDAY, MARCH 28, 1919.

LABOUR NEGOTIATIONS.

As we go to press the strike cloud which has been hanging over the community for some weeks seems about to lift, and in our next issue we hope to be able to announce that settlements have been reached with the miners, transport workers and railwaymen. So far as the miners are concerned, the leaders have definitely decided to recommend the men to accept the offer that has been made by the Government on the recommendations of the Sankey Report, which are summarised in our Industrial Notes. A ballot is to be taken for or against acceptance, but there is practically no doubt that the men will accept the advice of the leaders. On the ballot paper the offer is set out in the following terms: "(1) *Hours*: A reduction of 1 hour per day in the hours of underground workers from July 16, 1919, and, 'subject to the economic position of the industry at the end of 1920,' a further reduction of 1 hour from July 13, 1921. (2) *Surface workers' hours*: 46½ working hours per week, exclusive of meal times, from July 16, 1919. (3) *Wages*: An increase of 2*s.* per day worked to adult colliery workers, and 1*s.* per day worked for colliery workers under 16 years of age employed in coal mines or at the pit-heads of coal mines; this to apply as and from January 9, 1919. *Nationalisation*: In view of the statement in the report of the chairman of the Commission that 'the present system of ownership stands condemned,' and that 'the colliery workers shall in the future have an effective voice in the direction of the mines,' the Government have decided that the Commission must report on the question of the nationalisation of the mining industry by May 20, 1919."

As regards the transport workers who have been negotiating with representatives of the employers, the only unsettled section is that which relates to the hours and wages of omnibus workers, and this was the subject of discussion with the employers at a meeting held on Thursday, the result of which had not been made public at the time of our going to press. With regard to railwaymen, a point had been reached at which the negotiating committees of the two trade unions had definitely decided to recommend the acceptance of the Government offer, and, subject to the concurrence of a delegate meeting, there is every reason to believe that by the time this appears an agreement will have been reached.

So far as railwaymen are concerned, in our issue of February 28 last we gave full particulars of their demands. The Railway Executive Committee have acted on behalf of the Government as negotiators in the matter. Sir Albert Stanley has presided at most of the meetings, and on a number of occasions the Minister of Labour (Sir Robert Horne) and the Minister of Reconstruction (Sir Auckland Geddes) have been present. That all parties to the negotiations have had an extremely difficult task is apparent from the fact that, after having carried the subject to a point at which a definite offer had been made on behalf of the Government, it was rejected by a delegate meeting of the National Union of Railwaymen on March 14. The resolution carried at that meeting indicates the truculent attitude then adopted by the railwaymen; in terms it was as follows:—

"That this Congress hereby instruct our Executive Committee to notify the Railway Executive that no settlement will be accepted by us which does not cover all our members, without interference from any outside body.

"That this Congress, having heard the report of our Executive Committee on the negotiations which have taken place on the national programme, herewith express our utmost dissatisfaction and disgust at the parsimonious manner in which the Railway Executive have dealt with the same since the programme was first presented.

"We refuse to compromise upon the national programme, which is the carefully-considered irreducible minimum, and we therefore instruct our Executive Committee to convey this decision to the Railway Executive and the Government, and to emphasise our determination in the strongest terms and report back to this Congress by March 20.

"Further we demand that the settlement, when made, shall be retrospective from the date when the programme was submitted to the Railway Executive Committee."

It does not need to be pointed out that, if any body of workers puts forward a programme and insists that, no matter how extreme it may be, nothing short of it will be accepted, it can only lead to an appeal to force, much as that appeal is to be regretted. The suggestion that there was unnecessary delay in conducting the negotiations is absurd when it is remembered that some hundreds of grades are concerned in the application, that their conditions of service have been built up as the result of years of experience and that, with the best intentions in the world, it is not possible to draft and agree to new conditions without very careful consideration. Moreover, the Railway Executive Committee have been most unwarrantably attacked in the daily press in regard to the matter. It is true that the decision of the Government to set up a committee to review wages and other conditions of service of railwaymen in Great Britain and Ireland was arrived at in December last following the concession—on the eve of the General Election—of the 8-hour day, but it was not until towards the end of January that the Railway Executive Committee were asked to take the matter in hand, and we have positive evidence of the fact that the committee then set to work with the utmost despatch. When it is borne in mind that the railwaymen demand the standardisation of conditions of service on all railways, whether large or small, and that there was a clause in the programme to the effect that there should be equal representation, both national and local, for the National Union of Railwaymen on the management of all railways, it will be seen that the negotiations were of a very delicate character and involved matters of vital importance to the railway industry.

We are willing to believe that Mr. J. H. Thomas has had a difficult task in handling the situation on behalf of the National Union of Railwaymen, but are somewhat inclined to think that in his earlier speeches he gave undue encouragement to the men to expect that their programme represented a minimum of demands instead of something that might be modified by negotiations. Now he has great difficulty in getting the more extreme members of his union to take a moderate view, and to realise the satisfactory character of the terms offered them. The Government have wisely taken a firm stand regarding the proposal that workers in the railway shops should have the same terms as are offered to the railway operative staff. Apart from the question as to what proportion of men in the shops belong to the National Union of Railwaymen, there is the fact that many in the shops belong to other unions, notably the Amalgamated Society of Engineers. Thus, were the terms conceded to all the shopmen, members of unions other than that of Railwaymen would be working under different conditions than those of their fellow-workers in other departments of engineering. This would lead to great complications if not disputes. This, too, is only one of the difficulties.

As we have said, however, the negotiations have reached a point when there is every hope that a settlement will be come to. In the meantime no useful purpose would be served by reciting particulars of the offers that have been made since they are still the subject of negotiation. That the concessions will involve an enormously increased burden upon the State will be apparent from the announcement made by Mr. Bonar Law in the

House of Commons on the 20th inst., to the effect that they are estimated, roughly, to involve an additional expenditure of over 10,000,000*l.* per annum.

SPECTRUM ANALYSIS AND ATOMIC STRUCTURE.

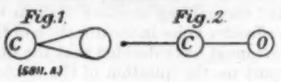
In his second Royal Institution lecture, of March 15, on "Spectrum Analysis and its Application to Atomic Structure," Sir J. J. Thomson, O.M., P.R.S., first referred again to the experimental evidence of a close connection between the luminosity of a flame and the electrical processes going on in it. In his demonstration of the previous lecture Sir Joseph had proved that the current of a battery passed much more easily through the flame of a Bunsen burner when a trace of sodium chloride was introduced into the flame, so that the yellow sodium light was visible, than when no sodium salt was present. Such a close connection would naturally be expected to exist if light consisted of electromagnetic waves. In the further demonstration of this phenomenon, given in the second lecture, a Wimshurst electric machine replaced the battery. A Bunsen flame was burning near the ball terminals of the machine; a bead of sodium salt was introduced into the flame, and the machine turned; the yellow flame was distinctly deflected and drawn towards the negative pole of the machine, whilst the ordinary gas flame itself was not deflected. That indicated, Sir Joseph remarked, that the emission of sodium light was associated with positively-charged luminous particles. Opinions were divided, as he had previously stated, as to the question whether the luminosity was observed while the particles were electrified, or whether the electrification was a preliminary stage, and whether a further process had to take place before the flame became luminous. He himself believed that the luminosity was due to the return of the negative electricity to the atom, and that the electrification was preliminary. Direct experimental evidence supporting this latter view was difficult to adduce, and for the present he would content himself with indirect evidence. He took again a Bunsen flame in which sodium salt was vaporised, and he further introduced into that flame some chloroform vapour. Chloroform [trichlormethane] contained chlorine which was a strongly electro-negative element and had a great attraction for negative electricity; the chlorine hence mopped the negative electricity in the flame up, so to say. If now the luminosity were due to the return of the negative electron to the atom and to the electric neutralisation of the atom, then the chlorine, by taking away the negative electron, should oppose that reunion and the neutralisation of the atom, and should diminish the luminosity of the sodium flame. This was indeed observed though the decomposed chloroform itself imparted a yellowish tint to the flame. That experiment seemed strongly to favour the argument that the flame lost its luminosity because the sodium was deprived of its negative electrons which could not return to their atoms.

Professor Thomson proceeded to show an experiment in which, he said, the advocates of the contrary view found one of their strong arguments. The apparatus consisted of an inverted glass flask with long neck; through the neck was introduced a wire ending about the centre of the bulb in a point, the anode, on which some strontia had been smeared; the anode was surrounded by a fairly stout short spiral of aluminium wire, the kathode of the arrangement. When the current was turned on, and the anode had become hot, after a little while, positive rays were emitted from the anode, the positive particles being the actual molecules of strontia; a stream of ruddy light was then seen to shoot upwards from the anode, and this column, Sir Joseph explained, showed the red spectrum lines of strontium. That seemed to be a clear case of a production of luminous positively-charged particles. If we looked deeper into the question, however, the important conclusion drawn seemed hardly to be borne out. If positive electrification were alone required, the luminosity should be visible as soon as the discharge passed. But the luminosity was faint at first, and it was only when gas came off the walls of the flask, and the strontia molecules struck gas particles tearing off from them electrons that the red colour became perceptible. We were not obliged to believe that the positive particles themselves were the seats of the luminosity; it was really the return of the electron to the atom which had been deprived of it that excited the luminous vibrations.

It was further not necessary, on the other hand, Sir Joseph continued, to take the view in all cases that the electrons were driven far away from their parent atoms. If real expulsion were indispensable we should not have any cases of luminosity without positive electrification or ionisation. Yet such cases existed. An experiment due to R. W. Wood would exemplify that. Sir Joseph showed a glass bulb containing some iodine vapour at very low gas pressure. The violet colour of the iodine vapour was not perceptible; but when the bulb was held in the lantern beam, the beam seemed to cross the bulb in a band of yellowish fluorescence. This vapour, however, did not show a trace of electric conductivity or ionisation; yet it could be demonstrated that iodine vapour in this fluorescent state was more easily made electrically conducting or ionised (by Röntgen rays, *e.g.*) than when not fluorescent. Many other gases and liquids were known to become fluorescent though there was no direct evidence of any concomitant ionisation, but the fluorescent facilitated the ionisations as in the case of iodine.

There was another point which had a bearing on this consideration: light was excited more easily in the salts of a metal than in the metal itself. Before demonstrating this point Sir Joseph wished to state the problem more definitely in a diagrammatic form. Suppose we had the molecule of carbon monoxide. The chemist assumed the two atoms of carbon and oxygen to be held together by a double bond C = O; electrically that meant that one double positive charge was united with two negative charges by two bonds (Fig. 1). If we caused one of these electrons to go off, the so far neutral atom would become positively charged. But the electron need not actually be expelled; it might only be displaced, as indicated in Fig. 2, the other electron remaining within the oxygen.

Fig. 1. *Fig. 2.*



(Sir J. J.)

In that case there would not be any apparent ionisation, no free electricity; yet the one electron might, in returning to its normal position, excite luminosity. Thus one could understand that it was not always necessary actually to detach the electron from its atom or molecule to call forth luminosity; displacement, tearing the two atoms apart, might leave the atom polarised and thus facilitate the production of luminosity. There were very striking experimental observations favouring this view. Certain zinc salts made the Bunsen flame luminous when put into it, but according to McLennan metallic zinc vapours themselves did not call forth any luminosity, though there was relatively more zinc present in the latter case. Mercury and most metals gave the characteristic flame when present as vapours; not so with zinc, however, at least not at relatively low temperatures. Sir Joseph's demonstration of these effects was given with the aid of the alloy of potassium and sodium, which looks very much like mercury, but oxidises very easily and is very awkward to handle. A pool of this

Fig. 3.

(Sir J. J.)

alloy had been placed in the bulb at the bottom of a discharge tube (see Fig. 3); K is the kathode, A the disc anode through the central opening in which the anode rays pass down the narrow tube and fall upon the alloy; the lateral connection C leads to the charcoal tube required for maintaining the high vacuum which is necessary for the experiment; the tube B serves for introducing the alloy. When the alloy was bombarded by positive rays, and the rays hit a speck of oxide, Sir Joseph explained, the yellow sodium light was seen by those near the apparatus; when the bright metallic surface was struck, no sodium light was emitted; since now the rays cleared the surface of oxide, the luminosity disappeared again, but could be restored by shaking the tube a little, which brought more oxide within the reach of the rays.

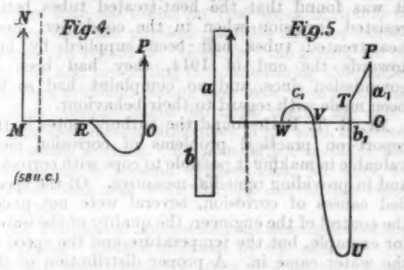
Coming back to the question of a direct proof of the view that luminosity was associated with the return of the electron to the atom, Sir Joseph referred again to the absorption spectra, produced when there was something in the absorbing body capable of vibrating with the period of the light falling upon it. If this light were given out by particles when positively electrified, then no light should be absorbed by an electrically-neutral vapour. But when a flame of sodium vapour, free from any electric charge, was interposed in the beam of the lantern which was producing a spectrum on the screen, the inverted black sodium line D appeared in the spectrum.

A great deal of photographic work had, after the early researches by Dewar and Liveing, Kayser and Runge, and others, lately been done by R. W. Wood and by the late P. V. Bevan, especially on the absorption spectra of the cold vapours of the alkali metals. Wood found in the absorption spectrum of sodium 48 lines extending into the remote ultraviolet, and 22 of these, that is nearly half of the whole number, were crowded in the ultraviolet near λ 2,417 Angström units; Bevan found 15 and more new lines in the absorption spectra of the other alkali metals, bringing the number of these lines up to 24 in the case of potassium, to 30 in the case of rubidium and to 24 in the case of caesium. All these absorption lines had also been identified in the bright-line emission spectra, but the absorption spectra represented special classes. For all the absorption lines belonged to the principal series of the element [the term to be explained in another lecture], but certain lines of the subordinate series were never observed reversed. It seemed that electrified particles were required to call forth the subordinate series, and these were mostly positively electrified, Sir Joseph thought, though negatively electrified particles also took part in the phenomenon. The study of positive-ray photography had convinced the lecturer that the atoms might, in the discharge tubes, lose one or even two electrons and travel on with their positive charges, whilst other particles showed by their deflection in the opposite direction that they had travelled as negatively-charged atoms.

At this stage, Sir Joseph continued, it would make things easier if we got a definite picture for the atom into our minds. The model he would take consisted of negative charges held together by a positive charge, and on that view matter would consist of minute negative electrons and of positive charges, possibly equally minute. The space actually occupied would be infinitesimal. One might ask, how that view was consistent with the different rates of the propagation of light through different media of matter? Light travelled through glass and water more slowly than through empty space; if glass and water differed very little from empty space, however, why should the velocity of light be affected in this way? This question of the variation of the velocity of light in different media was slurred over a good deal in text-books and lectures. The inquirer was referred to calculus, but a physical explanation was not offered. He himself would say that waves travelled through glass with the same velocity as through empty space, but the glass, the medium, superposed another effect.

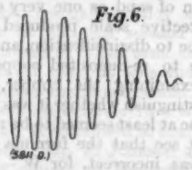
Supposing, in the first instance, we had a thin layer or belt of electrons grouped in a plane as indicated by the dotted line in Fig. 4, and a pulse or flash of electromagnetic force, represented by the line M N, was passing through the belt from left to right, stirring the electrons up into giving out light; let the observer be at O. The force reaching the observer in the light from the pulse itself would be represented by the line O P. Light would also reach O from the electrons, but the

electric force in this light from the electrons was in the opposite direction to that in the pulse which excited it. The light from the electrons would have a longer path to travel than that coming in the direction M O and would reach O later; the positive impulse O P would hence be followed by a negative impulse, and O P would have a negative tail O R added to it. Next consider instead of the pulse a simple harmonious wave of electromagnetic force, coarsely indicated in Fig. 5 by *a b*, *a* being the front, *b* the rear of the wave. The first part of the wave would reach O all right, but it would be followed by a negative tail which would reduce the positive forces which followed to P T. When the negative part of the wave arrived at O, the negative tail



produced by the positive part in front would still be coming in and would increase the electro force in the front position of the negative part T U; the negative part would then develop its own tail U V. Another tail V W in the positive direction would form again as a new layer of electrons was reached, and the distribution would then be represented by Fig. 5. Thus energy would be taken by the electrons from the front part of the wave (now a_1) and given up in the rear, shifting to b_1 and c_1. The energy thus moved backward down the wave, so that the rate of propagation of energy would be less than that of the wave. In this way light might be understood to travel through a medium like glass.

Returning to his model of the atom and taking the simplest case of the hydrogen atom, in which there was one positive and one negative charge, Sir Joseph asked, how that system was kept in equilibrium. The usual view was that the equilibrium was maintained because the electron described a planetary orbit round the positive charge. That was not the only possible view, nor, he thought, the right one. The calculations of the forces involved in that assumption necessitated extrapolations on an extravagant scale. When we dealt with what might be called mechanical distances, the forces varied inversely as the squares of the distances. But those mechanical distances were infinitely large when compared with the distances between the charges in the atom. It might be natural to suppose that the square law held for those minute distances as well; but we had no evidence whatever to that effect, and there was no direct experimental test extant. The forces inside the atom might be entirely different, and that was his suggestion. He thought that the forces varied as widely within the radius of the atom as was indicated by the oscillatory curve of Fig. 6, and that the square law only became valid a long way



off. When we denoted the reciprocal of the distance by u, the force would vary as u^2 on the general view. If the force were represented by $u^2 \frac{(\sin cu)}{cu}$, the force would, at large distances, still vary as u^2, whilst at small distances it would vanish periodically, and in each of these positions, marked by the points, the electron would be in equilibrium. To understand the complex character of spectra we had further to believe in there being different kinds of atoms of the same element differing as to their momentary conditions. Each spectrum line was given out by a particular atom, in a particular condition; the number of these kinds of atoms was infinite, and from the study of the absorption spectra we could estimate the relative numbers of particular atoms. The D line of sodium seemed to be given out by an electron furthest away from the centre; the line next to it was given out by an electron nearer to the centre, and so on. From the dispersion of the spectra Bevan had calculated that one in every 12 atoms of radiating sodium would emit the D line; the excitations of the lines further towards the violet end would be far rarer occurrences; the line next to D would only be produced by one atom in every 2,000, and the line further away be 1 atom in 5,000.

THE INSTITUTE OF METALS.

THE eleventh annual general meeting of the Institute of Metals was opened on Tuesday afternoon last, at the Hall of the Chemical Society, Burlington House, Piccadilly, W., Professor H. C. H. Carpenter, F.R.S., the president, occupying the chair.

REPORT OF THE COUNCIL.

In their annual report, the council recalled with deep thankfulness the fact that during the year ended December 31, 1918, hostilities came to an end and an armistice had been signed on November 11; they trusted that in the ensuing year a peace of justice would be established. During the year, the activities of the Institute, which had long been mobilised in aid of the prosecution of the war in every branch of non-ferrous metallurgy, were still further developed, and there was every reason for thinking that this assistance had its due influence in contributing to the defeat of the enemy Powers. It was quite certain that commercial and industrial competition between the nations of the world would be very keen, and it therefore behoved the Institute, the report stated, to be ready to assist the non-ferrous metal industry to the fullest extent of its powers and to see that there was no cessation in the improvement of technical processes which had been so marked a feature of the industry during the period of the war. The membership on December 31, 1917, was 888, but by May last it had reached 1,000, and by the end of 1918 had become 1,086, a net increase of 198 during the year.

The work of the Corrosion Research Committee had been carried on vigorously during the year. The results of much of this work were embodied in the Fourth Report, which was presented at the same meeting, and is dealt with further on. The Government grant-in-aid remained at 1,000*l.* per annum, and that of the British Electrical and Allied Manufacturers' Association at 450*l.* per annum, whilst the contribution of the Brass and Copper Tube Association had been raised to 300*l.* per annum. In addition to continuing the investigation into the cause or causes of the corrosion of condenser tubes at sea, as well as on land by fresh water, the subject of corrosion of non-ferrous metals by the atmosphere had received attention, and a special Atmospheric Corrosion Research Committee had been set up, conjointly with the Royal Institution of British Architects and various trades associations, to conduct researches into this aspect of the corrosion problems.

The council had accorded to the secretary permission to undertake for the Department of Scientific and Industrial Research the duty of conducting an inquiry relative to the manufactured products of copper and copper alloys, with the object of initiating researches having as their aim the removal of existing troubles and the obtaining of materials possessing the required properties.

The membership of the Birmingham Section for the eighth session was, members 138 and associates 48. The council reported with pleasure the formation of a Local Section of the Institute in Sheffield, under the chairmanship of Mr. W. R. Barclay. A request, on behalf of members resident in the Glasgow district, had been received by the council for permission to form a Local Section in Glasgow. The desired permission had been gladly given, and steps were now being taken to organise this new section.

During the past financial year, 639 copies of the Journal were sold, bringing in a revenue of 559*l.* 1*s.* 1*d.*, as compared with 415*l.* 8*s.* 4*d.* in the previous year. The cost of producing the Journal had increased very greatly, but the council had decided to incur this expenditure rather than to issue the Journal in a less complete form than heretofore, or in other than the usual strong cloth binding.

The report of the hon. treasurer, Mr. A. E. Seaton, M.I.C.E., showed that notwithstanding the very considerable and unavoidable increase in expenditure—the expenditure in 1918 being 2,404*l.*, as against 1,618*l.* in 1917—the year concluded with a credit balance of 318*l.* This satisfactory result had been mainly due to the great increase in membership and the receipts produced thereby.

After the reading of the report, the chairman spoke a few words with reference to the satisfactory situation of the Institute which was largely due to the work of the different committees. Much was to be hoped for in future from the work of the local sections. In that to be formed in Manchester both ferrous and non-ferrous metallurgists were to become members; it was felt that these members could give each other much invaluable information, and it was hoped that the other local sections would follow the same course. It was hoped also to resume the autumn provincial meetings this year, and a hearty invitation had been received from Sheffield; the meeting would take place in that city probably towards the end of next September.

COMMITTEE ON CORROSION.

On calling upon Dr. G. B. Bengough to read the Fourth Report of the Corrosion Committee, the chairman announced that a report would have been presented already a year ago had it not been for a request formulated by the Government that it should be held over during the war. We print an abstract of this Fourth Report on page 417 of the present issue. The report calls attention to a pre-oxidising process, the treatment being as follows in the case of 70:30 brass or Admiralty alloy. The finished tube is heated in an oxidising atmosphere for half an hour, at a temperature of 280 deg. C. ± 20 deg. C. It is then put into use with the oxide scale on it, *i.e.*, without pickling or further treatment. It has been found that this heat treatment does not affect the mechanical properties of the tube sufficiently to interfere with the making of a tight joint by the use of ferrules. The heating periods and temperatures vary with the alloys. The tubes thus treated should have a good, smooth and uniform surface. Tubes of various types of brass so treated have given good results so far at Brighton, in comparison with ordinary tubes of similar composition, but it is not yet certain that such tubes will resist the active attack set up by certain deposits.

Engineer Vice-Admiral Sir George Goodwin, who opened the discussion, said the report greatly increased our knowledge of the causes of corrosion, and for this reason, in combination with the suggestions it put forward for arresting or retarding corrosion, it formed a most valuable contribution to the Proceedings of the Institute. He congratulated the authors on their achievements, these were of a highly scientific character. He then referred to the report alluded to by the chairman which was ready twelve months ago; at that time that said report would have been useful to us, but it would have also been found most useful by the enemy, and he (the speaker) was very reluctantly compelled to ask the Institute to defer its publication. It had been found that the ships belonging to the allied Powers suffered from the corrosion difficulty and, also, that the German ships suffered from that difficulty even to a larger extent than our own did, for the proportion of condenser tubes which failed in the British Navy was very low indeed, thanks to the very great care displayed by the manufacturers in this country; this satisfactory state of affairs was certainly due to the British manufacturers' efforts. But, notwithstanding, the small proportion of condenser tubes which failed gave no

end of trouble. The Navy had to use a type of boiler which was very sensitive to the feed water; immediately salt water was admitted into the boiler, then the corrosion risks commenced. The trouble might commence in a new ship in the early life of the tubes; of the 30,000 tubes there might occur difficulties with probably about 12 and if these could be seen to immediately there would not be much further trouble afterwards. He asked that the few causes of failure we still now had be removed, for in war time the replacing of failed tubes caused much trouble indeed. The report indicated some method of retarding or arresting corrosion, and dealt also with the electrolytic protection of tubes. He (the speaker) had tried electrolytic protection many years ago; in recent years several improvements had been carried out in this method, and from exhaustive trials made it had been found to give now much better results than were obtained formerly. Under the heading of electrolytic protection, the report said the proper solution was held to be the discovery of a tube which could be depended upon, without external assistance, for a life of a definite length under given conditions, and free from unexpected failures at irregular intervals, and this statement combined with others on the same subject held out hopes for a solution of the difficulties now encountered. The pre-oxidising of the tubes was a method which had always appealed to the Admiralty, they had experimented with it in many forms and it was worth trying exhaustively. They had placed pre-oxidised tubes in one condenser and ordinary tubes in the neighbouring one, and these tubes could be examined from time to time. In perhaps a period of three years from now they might be able to give a full statement on the point, for both the pre-oxidised and the non-treated tubes were so far in excellent condition. The Admiralty had found the report a good one, and many good results were expected from it.

Professor Armstrong, who followed, said the report was one of very great practical value; it was a considerable step forward to arrive at the conviction that it was internal rather than external conditions which came into play in the matter of corrosion. He would not deal with the practical side of the question, but he felt much distressed at the fact that the work contained so many uncertainties on the theoretical side. Our theoretical outlook seemed to be very far behind the needs of practice. For example, the authors had said that the initial action of distilled water on zinc was a process of chemical oxidation rather than electrochemical displacement, and the action of sea-water was also chemical rather than electrochemical. He (the speaker) asked what was meant by a chemical action, what constituted it, what was the distinction between the two terms. It should be possible for us to arrive at a true attitude of mind in regard to questions of this kind, for we were, so far, undecided on our own particular side. Referring to the slides which were shown to illustrate the working of corrosion, Professor Armstrong added that the results illustrated were in accordance with theory; there were perodixation phenomena to a great extent behind corrosion, and many curious polarisation effects, and we had to get our minds into a more correct state in regard to the theory phenomena when we should be better able to approximate to truth in the matter of practice. With a correct theory we should be all the better off.

Dr. C. H. Desch, viewing the report from the practical side, found that it would be of great assistance in enabling us to solve the corrosion problems. A particularly interesting point which had been brought forward was the finding of a copper rich alloy on the surface of tubes and the importance of that layer in regard to corrosion. We were still a long way from a satisfactory position in the matter of the mechanism of corrosion. He thought that we had neglected too long the work carried out many years ago by Professor Armstrong with reference to the corrosion of iron. In past experiments one had arrived at the nature of the rusting practice in iron. He remained unconvinced in regard to several statements made by the authors on the process of oxidation.

After a few words by Mr. Arnold Philip dealing with electrolytic action for stopping corrosion of different metals, and explaining how that action took place in different circumstances and with the Cumberland process when the life of a condenser tube could be expected to extend over twenty-five years, Mr. J. Christie said he was a staunch advocate of electrolytic protection, and was very glad to read the authors' comments upon it. In the Brighton experiments, the graphitisation of the cast-iron was the cause of corrosion setting up, and if that could be stopped then corrosion would be arrested to a very great degree indeed; graphite particles finished by finding their way into the steam turbines and thence into the condensers, where they originated the trouble. Since he had used the protection, he had had only two failures, and those he attributed entirely to the graphite which had settled on the surface of the tubes, which then had been pitted right through. But he emphasised the fact that the protection process had to be applied from the start, before the trouble began. It would be most interesting to obtain from Admiral Goodwin information in regard to the alloys used in the condensers of the German ships, and to the means of protection, if any, which were used in them. The electrolytic protection method was greatly to be recommended, since it increased the life of the tubes up to as long as twenty years.

Dr. J. Newton Friend, who followed, stated that it was the activities displayed by the Institute in the matter of corrosion which had attracted him and had induced him to became a member. He queried an equation by the authors. They had given $(W - w) + M = n$, where W = original weight of the specimen; w = weight of specimen after test; M = weight of metal found in liquid either in solution or suspension; m = weight of metal in the scale and n = weight of non-metallic part of scale; $m + n$ = therefore, weight of scale. He (the speaker) would write the equation $M - (W - w) = n$. But he agreed to a certain extent with the authors in regard to the difficulty of determining the degree of corrosion by weight, although he had found that a large amount of useful information could be gathered from the loss in weight of the specimens. The authors' figures of losses in weight were, on the other hand, so exceedingly small that they could be said to be practically useless for arriving at reliable data. The losses in weight, when they could be found in a relatively high percentage, were valuable as a means of estimation. But this was not the only means available. It might frequently happen that a tube became perforated through and be lost in consequence, although it had not rusted to any extent at all. In regard to the depth of pitting, he (the speaker) had gathered useful information from the tensile strength of the material. It was not always possible to clear out the pit in the metal completely. The authors had experimented with samples suspended vertically and also horizontally, he (the speaker) had carried out similar experiments using iron; he showed how they were suspended and pointed out where pitting occurred in potassium chloride. The results of practical work given in the report would be of the greatest value; but he agreed with Professor Armstrong as to the theoretical aspects. In order to theorise correctly it was necessary to eliminate the external factors. It had generally been assumed that a difference in potential preceded chemical action, but he (the speaker) was not sure whether the reverse were not the fact.

Mr. F. Tomlinson found that owing to the publication of the report one now had practical results to depend upon, and as a manufacturer responsible for condenser tubes he was much interested in the authors' work. Admiral Goodwin had spoken truly when he remarked upon the efforts made by the manufacturers to deliver perfectly sound tubes throughout. It was difficult often to meet the Admiralty, and the makers had frequently themselves to set aside tubes on suspicion only. This was distressing, and he thought one result of the report would be to direct the Admiralty into placing still more confidence in the manufacturers and making one or two alterations in their specifications. The practical findings of the report were welcomed by the makers; such general findings, firms like that of the speaker had tried for some time past to impress upon the users of condenser tubes. In some cases, the abnormal corrosion could not be directly proved to be due to the chemical composition of the metal or to the physical properties of the tubes. He thought that in such cases, the blame possibly was put upon the manufacturers in the hope of obtaining a new set of condenser tubes cheaply. He (the speaker) issued, in 1905, a report on the question of condenser tubes, and if this were compared with the authors' table giving the causes of condenser tube and ferrule corrosion, it would be found that the authors' recommendations as remedies were embodied in his said report of 1905. The speaker heat-treated the tubes to a higher temperature than that referred to by the authors; this was an idea he obtained from America, where it was found that the heat-treated tubes better resisted corrosion when in the condenser. Such heat-treated tubes had been supplied by him towards the end of 1914, they had been in commission since, and no complaint had so far been made with regard to their behaviour.

Mr. R. T. Rolfe found the authors' notes in the report on practical problems of corrosion most valuable in making it possible to cope with corrosion and in providing remedial measures. Of the specified causes of corrosion, several were not under the control of the engineer, the quality of the water, for example, but the temperature and the speed of the water came in. A proper distribution of the steam could be arrived at by using suitable baffle plates. Screens could be used for the sludge, or settling tanks, but several devices were perhaps more expensive than the replacing of condenser tubes which failed. The foreign bodies which located on the tubes and the corrosive action they induced could be guarded against; the cast-iron parts, for example, were generally coated with tar as a preventive measure. The packing of condenser tubes was very important in practice; in this connection he showed a packing in which a lead washer was used to insure a metallic contact between the condenser tube and tube plate. It was interesting to note that at Brighton, with a lead packing, the Cumberland process being used, there were no further tube failures.

Dr. O. F. Hudson, in the course of a brief reply, said the authors were anxious that the theoretical side of the problems should be thoroughly discussed; they did not claim to have solved the whole problem. The hypothesis of direct oxidation was extremely helpful. On the other hand, if the electro-chemical theory were strictly applied, without the other hypothesis, the results might be unfruitful. A serious consideration of the direct oxidation hypothesis was very well worth while. The report pointed out several difficulties in the way of applying the electro-chemical theory in its simple form, and, so far, he did not think the discussion had brought out any real reply to those difficulties. He thanked Admiral Goodwin for his appreciative remarks on the practical applications of the work dealt with in the report. The admiral had emphasised the importance of considering early failures in condenser tubes, and he (the speaker) had the same experience in the matter of land stations, for the troubles were concentrated on the early life of the tubes. With further reference to the admiral's remarks, the authors had not had in view an absolutely incorrodible tube, but one that would show uniform rate of attack. He (the speaker) regarded the erosive action of sand as one very difficult to stop by any protective scale produced on the tube. With reference to dizincification, and as to whether this was due to re-deposited copper, or residual copper, in examining the copper, it was very difficult to distinguish whether it was re-deposited or residual; some at least seemed to be residual copper. He could not see that the formula questioned by Dr. Friend was incorrect, for $W - w$ might be a minus quantity; it might be either a positive or a negative quantity. The authors, he added, would deal with the remainder of the remarks by writing.

On the motion of the chairman, the authors were afforded a hearty vote of thanks for their work.

THE PROPERTIES OF SOME COPPER ALLOYS.

The next paper taken was the one on "The Properties of some Copper Alloys," by Dr. W.

Rosenhain and Mr. D. Hanson. It was read in abstract by the latter. We reproduce it in full on page 418 of the present issue.

The discussion was opened by Mr. J. Dewrance, who said it seemed unfortunate that metals such as those dealt with in the paper, having such good mechanical properties, should be so difficult to cast, and the authors were to be congratulated upon the manner in which they had been able to solve the difficulty. He (the speaker) would be surprised if the tube through which the molten metal was forced up from the crucible into the ingot would long survive the solvent action of the metal. It was true that the authors did state that with other metals, the tube gave trouble. Referring to the micro-sections shown, one metal being of a coarser texture than the other, he, (the speaker), found it strange that the physical qualities did not correspond. In regard to "teeming" the getting rid of the flux and preventing it from entering the mould had been problems lasting over many years, and the authors' results might be most useful for overcoming the practical difficulties of the kind, inherent to crucible working. By pouring the metal in the atmosphere it became oxidised, and all work to prevent that was work carried out in the right direction.

Mr. F. Johnson appreciated the description of the "teeming" method followed by the authors. He did not think, however, that this method would readily come into use in practice, since there were a large number of details to be observed. The previous heating of the ingot mould was a drawback. The idea of getting the metal from the bottom of the crucible was a good one, but this could be carried out on different lines, by pouring from the bottom with the use of a stopper. In endeavouring to provide a lid at the top of the mould, the authors should allow for the escape of the air, otherwise blowholes would be formed. From the authors' Table I the influence of manganese was noticeable. Their No. 6 alloy is harder than their No. 3 after the same treatment, and the only difference was 1 per cent. of manganese; but he did not think this quite showed that the rate at which manganese affected crystal growth during annealing was proved.

Mr. F. Tomlinson was pleased to see that the authors had found an application for his (the speaker's) "teeming" device. He thought, however, that if they had not tried to improve it, they would have obtained better results still. It was not necessary to heat the ingot mould; this was not a work's practice. He showed on the blackboard a sketch of one of his own ingot moulds, with delivery tube underneath, and the way in which the metal was made to flow up, by which arrangement he could fill up an 100-lb. ingot mould in 2 seconds. He used the process where the question of cost did not come in, but where it was necessary to obtain a very sound ingot.

Mr. O. W. Ellis mentioned a copper alloy containing 6 per cent. of manganese which had a yield stress of 6 tons per square inch, an ultimate stress of 21·5 tons and an elongation of 75 per cent.; after forging and annealing, the corresponding figures were 12 tons, 29 tons and 61 per cent. There were interesting points in one of the authors' lists of alloys, and it would be interesting to obtain the results of mechanical tests of various alloys made by separate members. In the authors' Table II, their 3 per cent. manganese alloy was similar in results to one of his (the speaker's) containing 1 per cent., instead of 3 per cent. of manganese; his figures were 11 tons, 23 tons and 31 per cent. annealed. Alloys containing iron and zinc, annealed after rolling gave respectively 13·4 tons, 23·4 tons and 48 per cent. He promised to contribute further results in writing. Mr. F. Johnson asked whether there was any danger of the vertical feed tube choking up.

Mr. W. R. Barclay said it would be interesting if the authors could give an idea of the casting temperature. Somewhat similar results to theirs had been obtained with the "box and plug" casting used in the steel trade. But the trouble was with the slag; there was also a difficulty in feeding and gat ends were produced rather extensively. Captain L. Aitchison asked for further data on the cupping tests carried out by the authors.

Mr. C. M. Auty, recording American experiments, said that better figures were obtained by adding iron instead of manganese to copper-aluminium alloys. This was confirmed by the chairman, who was under the impression that iron additions of about 3 per cent. had been found in the American experiments to have a very beneficial effect. The chairman also asked the exact sense in which the yield stress had to be taken and how it was determined.

Dr. Rosenhain, in the course of his reply, said the work in which they had been engaged and which formed the subject of the paper was emergency war work, and they had not the time nor the material to make it possible to enlarge further than they did upon the experiments. They dealt with only 20 lb. of material and for that small quantity they had to heat up the ingot mould previously to "teeming." They ought perhaps to have emphasised in the paper the fact that the quantities dealt with were very small comparatively. There was certainly a possible use for the device as arranged by them and it should not be so quickly put on one side. With alloys difficult to cast, they obtained perfectly clean and bright ingots, and this was a distinct achievement in the case of alloys containing manganese. The ingots were very sound, for they were feeding upwards under pressure all the time, forcing the metal up under a high head from below, by which means the ingot was exceedingly well fed and was sound throughout. Difficulties might arise from the fact that as they were dealing with very small quantities this involved a certain amount of overheating in the furnace. He foresaw an application of the method in the case of metal melted electrically, in an air-tight container as was the electric furnace. Foundrymen had gradually to become more mechanical. With the arrangement, no clearance in the crucible furnace was required for putting in the tongs for removing the crucible; the efficiency of the furnace could largely be increased thereby. The yield stress was that at which permanent elongation was first observable. In regard to the action of manganese, manganese did appear to have the property of retarding the rate of recrystallisation.

The thanks of the meeting were accorded to the authors of the paper.

On the Metallurgical Information Required by Engineers.

The last paper taken on Tuesday evening's meeting was one contributed by Lieut.-Col. C. F. Jenkin, R.A.F., "On the Metallurgical Information required by Engineers." This paper we also print in full on page 420 of the present issue.

The author said that in aircraft a new factor—weight—was of paramount importance, and new materials, such as aluminium alloys were constantly being tried and suggested for purposes for which they had never been used before. He asked on what properties of the material did its suitability for any particular purpose depend. In order that a metal might be suitable for a particular part of an engine it had to possess certain properties, which the engineer could easily specify, such, for instance, as stability and long life. But these were not among the properties which were known to the metallurgist, and when the engineer was asked for information, he was given a very different list of data, such as chemical analysis, micro-structure, mechanical tests, chemical reactions. There was also a list of vague words such as hardness, springiness, toughness and brittleness, fibrous or crystalline structure, resistance to shock, or vibration, or impact. A satisfactory answer to the problem, the author added, should not be beyond the reach of the metallurgist or engineer, if they worked in conjunction..

Captain L. Aitchison, who opened the discussion, said Colonel Jenkin put forward two opinions, first the properties which decided the suitability or otherwise of any material for use in a certain engine part, then the way in which these properties should be defined. In regard to this latter, it was probable that all metallurgists would agree as to the need of a much more definite method of testing material, with a view to expressing its nature in terms of the fundamental properties common to all materials. All metallurgists would also agree that this could only be done through the most intimate co-operation of metallurgists and engineers, and metallurgists would be more than anxious to co-operate with engineers in the search for fundamental information regarding materials. The fundamental properties required by a material to be used in an engine were defined by Colonel Jenkin as stability and long life. But it was probable that neither could be expressed as a simple function. Stability could not be expressed commercially in the same way as, say, specific gravity, and long life was controlled by many factors. It was therefore reasonable to say that it was a combination of the metallurgical properties of the material which would supply the most information in regard to the fundamental engineering properties. He (the speaker) then referred to a few of the metallurgical properties and said that three functions involved in the long life of a part were affected directly by the chemical composition, *i.e.*, permanence of the stability properties, soundness of the material, its purity and freedom from objectionable constituents. But it should be remembered that the material in the engine worked at different temperatures. There was also the decay of the material. Colonel Jenkin also referred to micro-structure, and in this connection, a known constitution meant more or less a known stability property and probably also a fairly well defined long life property. This was fairly well illustrated in the case of steels, and he (the speaker) illustrated as examples the austenitic, martensitic and pearlitic forms, the physical properties of each of which were known. It seemed reasonable to him (the speaker) that it would be upon the basis of constitution that the most satisfactory comparisons of materials would be made, the fundamental information required about them being the knowledge of the properties of the solid solutions of the various possible combinations in the constitution of the alloys in which they occurred. In short, it would seem that the metallurgist could offer to the engineer no complete information upon the fundamental properties defined by the author, but that he could offer other fundamental properties of the material which he might regard, rightly or wrongly, as likely to provide the necessary knowledge.

Professor Turner, who followed, found the author's paper most attractive. There was only one way of testing long life, and that was by putting an article to wear. A rail could last ten years and they had seen in the course of the previous discussions that a condenser tube could last twenty years, but the engineer did not want to wait twenty years to find out the life of a piece, he wanted to know now. Engineers had to come to the metallurgist and the latter would give them the best he had, without specifications, and staking his reputation on the quality of his product. When the engineers came to the metallurgist and asked him for steel rails that wore well, they found the metallurgist made analyses and physical tests for his own information and satisfaction; the engineers finding the metallurgist to employ these tests, they immediately required him to work to tests, and if they found the specifications not to give the results, they threw over chemical composition, micrography, &c., and asked for long life. There must be some sort of agreement between the two as to the best tests to make, and if the tests were not sufficient, it was to the engineers to suggest others.

Dr. Hatfield said the metallurgist was largely indebted to the engineers for the means employed in manufacture; it was for them to devise the test, they were responsible for the test the metallurgist employed. Here Dr. Hatfield illustrated a diagram showing the different and contradictory values of the different tests on the same steel. He found the great standby was the tensile test combined with torsional tests. Impact and alternating tests were valuable and brought out data which other tests did not.

Dr. Rosenhain thought there was a risk in testing to try to approximate to actual conditions, but accelerating them. It was possible to imitate practical conditions in a model; in a model one had as nearly as possible actual practice, but on a small scale. But in instances where the time factor came in, the law of proportion did not come in also. What was wanted in the testing laboratory

was to get as near as possible to some constant of the material and to find out further what combination of the physical constants was the best. Tests, also, should be made as simple as possible. The more complicated were the tests, the more difficult it was to arrive at uniformity between the various people.

Colonel Jenkin, in the course of a brief reply, thanked the meeting for the good spirit in which his remarks had been received. He thought Dr. Rosenhain had explained exactly his own feelings in the matter. Engineers could not intervene alone, the aid of the physicist was required in formulating fundamental properties. Experiments were being carried out with pistons, cylinders and other engine parts made of aluminium, for which parts one did not dream a short time ago that aluminium could be used. Aluminium crankshafts were also being asked for, and it was necessary to know what properties such a piece should have.

The meeting thanked Colonel Jenkin for his contribution to the proceedings and then adjourned.

The reading and discussion of papers were continued on Wednesday. We shall deal with this further matter in our next issue.

(To be continued.)

INDUSTRIAL NOTES.

MR. F. H. MCLEOD, Director of the Department of Labour Statistics, says, in *The Labour Gazette*, that the state of employment in February continued to be affected by the inevitable dislocation arising out of the enormous change over from war to peace conditions. The unemployment thus arising, however, is of a widely different character from that occurring at a time of trade depression caused by a general contraction in the demand for goods. At the present time the world generally is short of almost everything, and there will be an abundant amount of work to be done as soon as trade and industry have readjusted themselves to the new situation. It is satisfactory to observe from the statistics of the out-of-work donation that a large percentage of those who lodged out-of-work policies have now been absorbed in industry. The high percentage of demobilised men so absorbed is particularly noticeable. Wages continue to rise, and hours of labour are being reduced; at the same time the index number of retail prices of food and other items entering into the cost of living has fallen since the beginning of February from 120 per cent. to 115 per cent. above the pre-war level.

Trade unions with a net membership of 1,167,757, excluding those serving with the forces, reported 2·8 per cent. of their members as unemployed at the end of February, as compared with 2·5 per cent. at the end of January and 0·9 per cent. a year ago.

Of the 3,561,710 male and female workpeople insured against unemployment under the Acts of 1911 and 1916, the number unemployed at the end of February was 381,285 (or 10·71 per cent.), compared with 9·93 per cent. at the end of January, and 0·89 per cent. a year ago. The percentage for males was 8·05, and that for females was 18. In addition to these 381,285 workpeople, there were 567,335 persons (211,193 men and boys and 356,142 women and girls) in occupations not included under the National Insurance Acts, who were unemployed on February 28.

Excluding demobilised members of H.M. Forces, the number of persons, who were unemployed on each Friday in February, according to the statistics of the Government Out-of-Work Donation Scheme, was as follows: February 7, 670,433; February 14, 719,950; February 21, 748,311; February 28, 782,363. The number of demobilised members of H.M. Forces in receipt of out-of-work donation at the end of February was 166,257.

The number of men on the live registers of the Employment Exchanges on February 28 was 416,150, and the number of women was 549,261. The corresponding figures for January 31 were 273,876 and 453,912. The number of vacancies unfilled on February 28 was 51,369 for men and 63,698 for women, the corresponding figures for January 31 being 67,318 and 51,881.

Employment at coal mines continued good in February. At all collieries covered by the returns received the pits were working 5·72 days per week in the fortnight ended February 22, as compared with 5·51 days per week in the corresponding period of 1918. The number of workpeople employed showed an increase of 5·6 per cent. as compared with the previous month, and of 7·4 per cent. as compared with a year ago. At iron, shale and lead mines employment continued good, but at tin mines it was only moderate. Quarrying operations were interrupted by bad weather. In the pig-iron industry and at iron and steel works employment continued good. In the engineering trades there was a further decline, but skilled men continued to be fairly well employed. The shipbuilding trades were still affected by disputes in many districts, but otherwise employment continued fairly good. At tin plate and steel sheet mills employment was good, and showed a further improvement as compared with January, and a marked improvement as compared with a year ago. In most of the other metal trades employment was fairly good.

In the spinning branch of the cotton trade employment showed a decline as compared with the previous month; in the weaving branch it was very slack, and worse than in January. In the linen trade employment was slack in Scotland; in Ireland it was bad, and in the Belfast district 75 per cent. of the workpeople were working short time. In the textile bleaching industry employment continued slack; in the printing and dyeing sections it was bad. In the carpet trade employment continued fairly good. In the leather trades employment showed a decline, but was still fairly good; in the boot and shoe trades it was good on the whole.

Employment continued good in the brick, cement, pottery and glass trades. There was a further decline in the building trade, and employment generally was slack. In the furnishing and woodworking trades employment was good with coachbuilders and coopers and fairly good with millsawyers and in the furnishing section. In the paper, printing and bookbinding trades employment was also fairly good on the whole. The food preparation trades were well employed, and a considerable amount of overtime was worked in the sugar-refining industry.

With dock labourers employment was fair on the whole. At most of the principal ports the supply of seamen was greater than the demand. In agriculture the labour shortage became less acute, but skilled workers were still needed.

The changes in rates of wages (including war bonuses) reported to the department as having come into operation in February resulted in an increase of about 85,000*l.* in the weekly wages of 550,000 workpeople. The workpeople chiefly affected were those employed in the woollen and worsted industry, in the textile bleaching, dyeing and finishing trades, and at gas undertakings.

The principal bodies of workpeople affected by reductions in normal working hours were railway servants, for whom the principle of an 8-hour day was put into operation; iron and steel workers in certain districts, for whom a uniform 8-hour shift was adopted; and workers in the vehicle building and chemical industries, whose weekly hours were reduced to 47.

Following upon the sitting of the Coal Commission, three reports have been issued, (*a*) the chairman's report signed by Mr. Justice Sankey, Mr. A. Balfour, Sir A. Duckham and Sir T. Royden, (*b*) the mineowners' report signed by Mr. J. T. Forgie, Mr. R. W. Cooper and Mr. Evan Williams, and (*c*) the colliers' report signed by Mr. R. Smillie, Mr. F. Hodges, Mr. H. Smith, Sir L. C. Money, Mr. R. H. Tawney and Mr. Sidney Webb.

The chairman's report recommends that in the Coal Mines Regulation Act, 1908, the clauses limiting the hours of work underground be amended by substituting the word "seven" for "eight" as from July 16, 1919, and, subject to the economic position of the industry at the end of 1920, by substituting the word "six" for the word "eight" as from July 13, 1921. It recommends that as from July 16, 1919, the hours of persons employed at the surface be 46½ working hours per week, exclusive of meal times. It recommends, further, an increase in wages of 2*s.* per shift worked, or per day worked, in the case of the classes of colliery workers employed in coal mines or at the pitheads of coal mines, whose wages have in the past been regulated by colliery sliding scales; in the case of workers under 16 years of age, the advance to be 1*s.* The result of these recommendations means, besides the shortening of the working day underground by 1 hour from July 16, 1919, and probably by a further hour from July 13, 1921, the distribution of an additional sum of 30,000,000*l.* per annum as wages among the colliery workers, plus 13,000,000*l.* in decreased output.

The chairman's report also states that upon the evidence already given, the present system of ownership and working in the coal industry stands condemned, and some other system must be substituted for it, either nationalisation or a method of unification by national purchase, and, or, by joint control. No detailed scheme for nationalisation has as yet been submitted to the Commissioners, nor has any scheme for joint control been placed before them. But the signatories to the chairman's report "are prepared to report now that it is in the interests of the country that the colliery worker shall in the future have an effective voice in the direction of the mine. For a generation, the colliery worker has been educated socially and technically. The result is a great national asset. Why not use it?"

The report further suggests the collection of 1*d.* per ton on coal raised, the resulting sum (1,000,000*l.* a year on the present output) being used to improve the housing and amenities of each particular coal district.

To meet the decreased hours and the increased wages, a sum of 43,000,000*l.* is required this year. Partly to meet this, it is proposed, through the machinery of the Coal Mines Control Agreement, as amended for the purpose, to allow the coalowners to retain 1*s.* 2*d.* per ton of coal raised.

The following appendix to the chairman's report shows the various items of cost and profit on a ton of Derbyshire coal from its place underground to the time it reaches the consumer's cellar in London:—

Royalties, 4*d.*; wages, 13*s.* 5*d.*; supplies and stores, 3*s.* 6*d.*; administration, 5*d.*; depreciation, 4*d.*; owners' profit, 2*s.* 5*d.*; coal controller's profit, 9*d.*; total, 21*s.* 2*d.*

This 21*s.* 2*d.* is for coal as it comes from the pit. For household purposes it is screened to some extent, which makes the price of the best coal 23*s.* 5*d.* at the pit.

Pit-head price (screened), 23*s.* 5*d.*; railway rate, 6*s.* 3*d.*; wagon hire, 1*s.* 6*d.*; factor's charge 4*d.*; merchant's charge: Labour, 4*s.* 3*d.*; cartage, 2*s.* 10*d.*; establishment charges, 3*s.* 4*d.*; wastage, 7*d.*; management and interest, 3*d.*; profit, 1*s.* 3*d.*; total, 44*s.*

The mineowners' report says it was proved in the evidence that the average annual earnings of all colliery workers, both men and boys, were in the year 1913 82*l.*, and in the September quarter of 1918 at the rate of 169*l.*, equal to an increase of 106 per cent. since the outbreak of the war. The signatories to this report add that they have come to the conclusion that no greater increase than 1*s.* 6*d.* per day worked for persons 16 years of age and upwards, and 9*d.* for persons under that age can be made in the existing wages of colliery workers without seriously affecting our home industries. Such an advance would bring the present average earnings of the colliery workers to over 130 per cent. in excess of their earnings at the outbreak of war.

In regard to hours, the utmost extent to which the mineowners feel they can safely recommend a reduction is that in the case of persons employed below ground "seven" hours be substituted for "eight" in the Act, and that the hours of all surface workers at or about mines be fixed at 8 hours per day.

As regards nationalisation, or unification of ownership of collieries, the evidence is insufficient to enable the mineowners to pronounce any judgment.

The miners' report maintains the full demands which were reviewed by the Commission in its various sittings, a decision to be given now, on principle, in regard to the claim for nationalisation.

Since these reports were issued, a number of further conferences have been held. We deal in our leading article both with the colliery situation and with that of the railways.

BIRMINGHAM COMMERCIAL LIBRARY.—We are informed that in connection with the Commercial Library now being organised for the City of Birmingham, it is proposed to form a collection of trade catalogues which would become a medium of quick reference to the sources of supply of any particular class of goods. The chief object of the collection would be: (1) To secure representative instances of sound design in various branches of industry; (2) to bring the buyer into touch with the manufacturer or merchant. With the question of prices and discounts the Commercial Library is not concerned, and catalogues from which this information is omitted or cancelled would be quite suitable for inclusion in the collection. It would be a great help in the formation of such a collection if manufacturers would be good enough to send copies of their catalogues to the Chief Librarian, Ratcliff-place, Birmingham.

PERSONAL.—Mr. Philip S. Doherty will shortly cease his connection with Messrs. Haighs (Oldham), Limited. He has returned to his old offices, 25, Victoria-street, Westminster, London, S.W. 1, and will there continue his business as pumping engineer, &c., under the title of Philip S. Doherty and Co.—Messrs. Duggans, Limited, of Coventry, announce that, in order that the name of the firm may indicate the nature of the business carried on, they have decided to trade as Coventry Malleable, Limited, in conjunction with Duggans, Limited. The management and staff will remain the same as before.—We are informed by Automatic and Electric Furnaces, Limited, that owing to its being necessary for them to secure larger premises for their offices and works they have removed to 281 to 283, Gray's Inn-road, London, W.C. 1.—We have pleasure in announcing that the King of the Belgians has been graciously pleased to create Mr. Philip Dawson, M.Inst.C.E., M.I.Mech.E., M.I.E.E., Chevalier de l'Ordre de Leopold, in recognition of his services as a member of the Belgian Royal Commission on the electrification of the Belgian State Railways.

THE ACCURACY OF THE VENTURI TUBE.

TO THE EDITOR OF ENGINEERING.

SIR,—With regard to the suggestion that the accuracy of Venturi tubes is generally dependent upon up-stream conditions, I should like to give support to Mr. Hodgson's letter in your issue of the 14th inst. As an engineer who has had considerable experience of the Venturi tube in its application to the measurement of sewage flows, I should like to say that I have found the "Venturi meter" to be reasonably accurate even when operating under most unsatisfactory conditions and in situations where a long lead on the up-stream side of the meter was unobtainable.

In my view, Mr. Hodgson's figures of 5 per cent. is reasonable even under unfavourable conditions, as in many instances I have found the error rather less. I might add that I have carefully checked meter readings in such cases against the cubical contents of a concrete tank (2,420 sq. yards by 1 yard) into which the sewage was discharged, for the special purpose of checking the accuracy.

I have also examined Mr. Hodgson's manometer, referred to in his letter, and consider it to be a most ingenious, yet simple contrivance, for showing small variations of pressure, and which I should think will find very general use.

I am, dear Sir, yours faithfully,
OSWALD J. WILKINSON,
Assoc.M.Inst.C.E.

196, Deansgate, Manchester, March 20, 1919.

CIVIL AERIAL TRANSPORT.

TO THE EDITOR OF ENGINEERING.

SIR,—My copy of your issue of the 14th unfortunately went astray, and has only just been delivered, so that I was, up to the present, ignorant of Mr. Zaiman's "rebuke."

His second paragraph would be more to the point if Sir G. Greenhill had ever mentioned the "practical justification" of a scientific law. What he did speak of was the practical justification of a theory—a very different matter.

With reference to the question of the distance flown for a given quantity of petrol, the following may make the point clear.

It was shown in the article that the petrol consumption is an economical minimum when 50 per cent. of the power is spent in overcoming head resistance and the rest in driving up the air incline. Under these conditions we have:

$$\text{H.P.} = \frac{2\,K}{330\,A}\frac{W^2}{A}\left(\frac{12}{K}\right)^2$$

To allow for the reduction in weight due to consumption of petrol we can write:

$$\frac{dW}{ds} = \frac{1}{K}\frac{dW}{dt} = -\frac{p}{K} \times \text{H.P.}$$

$$= \times \frac{2\,p}{330\,A}\left(\frac{12}{K}\right)^2 W^2$$

where s is written for the distance traversed.

Thus:

$$-\int_{W}^{W-P}\frac{dW}{W^2} = \frac{2\,p}{330\,A}\left(\frac{12}{K}\right)^2\int_{0}^{L} ds$$

or:

$$\frac{1}{W-P} - \frac{1}{W} = \frac{2\,p}{330\,A}\left(\frac{12}{K}\right)^2 L$$

whence:

$$L = \frac{330\,A}{2\,p}\left(\frac{K}{12}\right)^2 \frac{P}{W(W-P)}$$

When no account was taken of this reduction in weight, the expression arrived at was:

$$L = \frac{330\,P}{2\,p\,W}\,n \quad \text{where } n = \frac{A}{W}\left(\frac{K}{12}\right)^2$$

or:

$$L = \frac{330}{2\,p}\left(\frac{K}{12}\right)^2\frac{P}{W^2}.$$

Comparing these two values of L it will be seen that the radius of action is increased in the ratio $\frac{W}{W-P}$ as stated in the article. Where is the "false assumption," and why can the accuracy "only be accidental"?

With regard to the air-density question, I might adopt Mr. Glauert's tactics and ask "What about that not unknown 'ancient,' to wit, Maxwell"? I prefer, however, to admit that I have not seen Mr. Dines' results, as I have been laid up for fifteen months. The jump from 18,000 ft. to 21,000 ft. seems large, but hardly sufficient to justify Mr. Glauert's attack. It is quite evident, as Mr. Zaiman points out, that any one who says "from 15,000 ft. to 20,000 ft." is speaking in round numbers.

Yours faithfully,
C. E. WOLFF.

2, Devonshire-street, Ardwick, Manchester,
March 24, 1919.

THE FATE OF THE GERMAN FLEET.

TO THE EDITOR OF ENGINEERING.

SIR,—We have already heard several reasons why the German war vessels should be sunk in mid-ocean, and we may hear more, but to engineers the idea of destruction is hateful. Their essential function is constructiveness or creativeness in the fullest sense of the word, and they abhor the mere suggestion that hundreds of thousands of tons of most valuable steel, which have cost hundreds of thousands of tons of coal, should be "spurlos" submerged like the fabulous Niebelungen hoard. One excuse given for the proposed destruction is that it might cost more to break up the ships than the scrap material would fetch in the metal market. Surely not. The armour plates are readily removed, and it would pay to form a company to melt them down. There are certainly a score of steel works' managers in this country who would be only too pleased to design and build a furnace into which whole armour plates could be charged. When once the armour is removed the engines and boilers could be taken out. There might be some difficulty with the hulls, but it should not pass the wit of engineers to devise machinery which would reduce them to suitable scrap metal. It might, however, be more profitable to use these hulls as breakwaters as suggested by your correspondents. To these suggestions I should like to add that the hulls might be very useful if they were to be placed where they would block the entrance to the Heligoland harbour.

I am, yours faithfully,
C. E. STROMEYER.

Lancefield, West Didsbury, March 13, 1919.

SITUATIONS VACANT.

TO THE EDITOR OF ENGINEERING.

SIR,—With reference to the letters which have been appearing in your columns during the last week or two on the subject "Situations Vacant," I should be glad to have the opportunity of supporting the statements of your correspondents as my experiences in applying for situations have been somewhat similar. It certainly looks as if our applications are not worth the paper they are written on, as without the necessary "Big Kick" we must not look for even an interview. Like your correspondent "G. R. R.," I also consider the present system, where we have to state in our applications "salary required," to be unfair and for several reasons, for instance:—

1. The salary which might be expected in one district may not suit another district.

2. In naming a certain figure as "salary required," and the advertiser considers it too large, the application is turned down, whereas if (considering the application to be suitable in every other way), the applicant were interviewed, the figure might be modified.

3. If in the event of a candidate being successful and a salary of 300*l.* agreed upon, on taking over the post it is found to be value for 600*l.*

The writer having acquired, at considerable sacrifice a first-class experience in shipbuilding and ship repairing, both practical and theoretical, has for some time back been trying to get a post on the management of a shipbuilding or ship repairs establishment, where he could both estimate for and take charge of the work. Whether the salary asked for is too large or too little, it seems to be most difficult even to secure an interview.

Yours truly,
"GENERAL AVERAGE."

March 17, 1919.

TO THE EDITOR OF ENGINEERING.

SIR,—The letters appearing in ENGINEERING, under the above heading, should serve a useful purpose as they show:—

(*a*) That employers use a form of advertising for assistants that is distinctly unfair to the latter.

(*b*) That by these methods, employers are going the wrong way about getting the best man for the job.

I think it is not unjust also to say:—

(*a*) That many employers do not want the best man to apply, having already filled the post by appointing someone who has obtained the job through personal influence.

Dealing with (*a*). An employer should surely know what the vacant post is worth in salary. By omitting to state salary he wastes the time of the man who is not good enough as well as the man who is capable of handling a bigger job. Secondly, the omission to advertise that a position has been filled, keeps applicants on tenterhooks for an unnecessary length of time, and possibly deters them from applying for other work.

Regarding (*b*). Where salary is not quoted, many of the most suitable men will not apply, as they are unaware of the scope of the job (as measured by pay) and are apt to think that the job is not worthy of their capabilities, or *vice versâ*.

By asking for too many qualifications in one man, employers are apt to get someone who knows a little of all subjects, and not enough of any one of them. A man may be a specialist in steam, electricity or motor-car engineering, but never can he be really proficient in all three, yet I have seen recently an advertisement for such a superman. Regarding (*c*). Facts are difficult to obtain, and more difficult still to publish, but most of us know of cases where a man has been put into a position to please his uncle or father (a director) and then the "vacant" post has been advertised to placate the other directors and shareholders. This is a distasteful topic, but the evil undoubtedly exists, and is a source of the gravest injustice to the unfortunate men who fancy they have a chance of obtaining the post.

Another frequent fault lies in the method of selecting from a number of candidates. This is often left finally to the commercial head of a concern who is apt to consider a man's price before his capabilities. I came across a case recently where a man of technical ability was required to manage a large and highly-specialised department. The applications were sent to the firm's consulting engineer for adjudication on the grounds of merit only. He picked the man whose qualifications best filled the bill. The matter was finally referred to the general manager (a non-technical man), who turned down the consulting engineer's decision for a man who asked a smaller salary, but had nothing like the qualifications desired by the consulting engineer.

Another thing one would like employers to realise is that it is useless to advertise for, say:—

"Assistant Works Manager, with Shop and D.O. experience. Must have engineering degree and have held similar position. Salary 350*l.*"

A good draughtsman can do better than that to-day. Finally, one would be very interested to hear the story of those who have advertised in the "situations wanted" column.

Yours truly,
A. H. CONSTANTINE.

March 20, 1919.

TO THE EDITOR OF ENGINEERING.

SIR,—Like several of your correspondents, I think it time that advertisements *re* vacancies were inserted under the proper name of advertising firms. It has come to my knowledge that a large proportion of these advertisements are not genuine at all. Some have turned out to be from correspondence tuition firms, who thereafter post circulars to applicants urging them to strengthen their weaknesses; some from firms whose only object has been to elicit other people's business affairs from applicants; others to obtain various kinds of information from applicants—merely "fishing" advertisements.

I know of no reason why a straightforward firm should not advertise in its own name, stating salary and afterwards advertising name of successful applicant.

In cases where firms do this, let the engineering staffs all over the country take a note of it, and see that they are classed "O.K." for business relations whenever possible. Good men will not gamble with anonymous advertisers.

Yours faithfully,
"OPEN HEARTH."

March 23, 1919.

THE AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS.—At the February meeting of "The American Institute of Mining Engineers," the Institute changed its name into "The American Institute of Mining and Metallurgical Engineers."

COMMERCIAL RECONSTRUCTION.—Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, inform us that they are now reorganising all the departments of their various works with a view to undertaking a wide range of commercial engineering products, and assisting thereby to meet the requirements of the engineering industry both at home and abroad in connection with the world's industrial reconstruction. In this connection they have now formed a Central Commercial Department, with headquarters at 8, Great George-street, Westminster, London, S.W. 1, and that this department will, from now onwards, control all matters relating to publicity and the commercial handling of the engineering products manufactured by all departments of the firm.

THE SIR ROBERT HADFIELD PRIZE.—(1) Sir Robert A. Hadfield, D.Sc., D.Met., F.R.S., vice-president of the Institution of Mechanical Engineers, has placed in the hands of the Institution the sum of 200*l.*, which with any income therefrom may be awarded at the discretion of the Council of the Institution as a prize or as prizes, for the description of a new and accurate method of determining the hardness of metals, especially of metals of a high degree of hardness. (2) The ordinary tests of hardness, such as are described in the Report of the Hardness Tests Research Committee (Proceedings of the Institution of Mechanical Engineers, 1916, pages 677 to 778), which should be consulted by competitors, fail to some extent when the hardness of the material exceeds about 600 to 800 Brinell. What is desired is the description of a research for or an investigation of some method of accurately determining hardness, suitable for application in metallurgical work in cases in which present methods partially fail. (3) The award or awards will be made by the Council of the Institution of Mechanical Engineers, whose decision will be in all cases final. (4) The council will consider annually all communications received, and may then award a prize or prizes. But in January, 1922, the offer of prizes will be withdrawn, and any unexpended balance of the prize fund will be diverted to any other purposes to be determined at the discretion of the council. (5) The council may award the whole or any part of the sum available at any time if a communication is received which, in their opinion, is of sufficient originality and importance and satisfies the object aimed at; or they may from time to time award portions of the fund, not exceeding in all 75*l.* in any one year, for communication which do not completely solve the problem, but which appear to advance the knowledge of methods of testing hardness. The Institution will probably be willing, and reserve the right, to publish in its Journal any communications for which a prize is awarded. (6) A communication should be accompanied by scale drawings of any new apparatus described, or by a model or an example of the apparatus itself. If the communication describes a new invention, likely to be of commercial value, it is desirable that provisional protection should have been obtained before it is submitted for consideration. (7) Communications should be addressed to the Secretary, the Institution of Mechanical Engineers, 11, Great George-street, Westminster, London, S.W. 1, and marked "Method of determining Hardness," and should reach him at least one month before January 1 in any year. Applications for the next award should thus be sent in before the end of November, 1919.

ELECTRICALLY-HEATED CRUCIBLES.

CONSTRUCTED BY THE MORGAN CRUCIBLE COMPANY, LIMITED, LONDON.

Fig. 1.

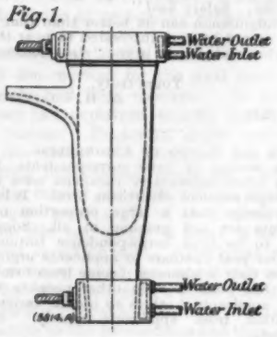


Fig. 2.

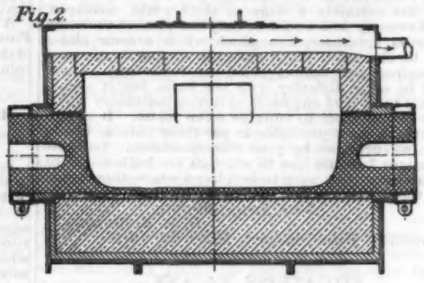


Fig. 3.

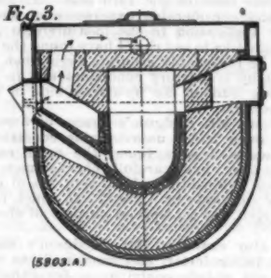


Fig. 4

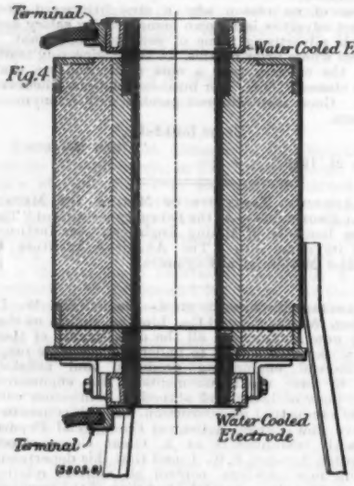
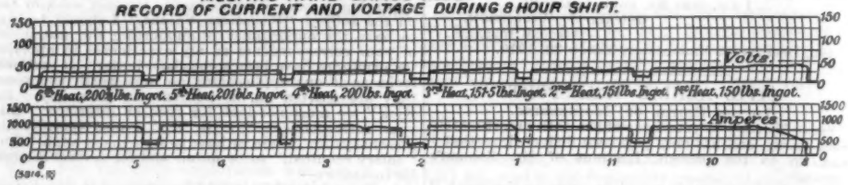


Fig. 5. 200 LB. ELECTRICALLY HEATED CRUCIBLE. MELTING HARD BRASS INGOT RECORD OF CURRENT AND VOLTAGE DURING 8 HOUR SHIFT.


Volts.
6th Heat, 200 lbs. Ingot. 5th Heat, 201 lbs. Ingot. 4th Heat, 200 lbs. Ingot. 3rd Heat, 151·5 lbs. Ingot. 2nd Heat, 151 lbs. Ingot. 1st Heat, 150 lbs. Ingot.
Amperes
(5916.B)

In our issue of October 18, 1918, vol. cvi, page 439—under the heading of the "New British and Key Industries Exhibition"—we drew attention to the special graphite crucibles made by the Morgan Crucible Company, Limited, of Battersea, S.W. 11, for the direct heating of brass, &c., the interesting and new feature being that the crucible is the container and the resister.

The company have continued their experimental research work, and as a result are in a position to supply not only crucibles similar to that shown in Fig. 1, which has a capacity of 200 lb. brass, but have also furnaces of unique design ready for regular use in foundries. The crucible is designed in such a way that the maximum heating effect is produced in the zone where it is required; the electrodes are at the top and bottom of the crucible and are water cooled, while the crucible is suitably mounted in a casing in such a manner that expansion and contraction are allowed for and all the advantages of the now well known tilting type of crucible furnace are secured.

This design is applicable to any foundry (provided the electrical power is available), where the management prefer to adhere to the well-tried crucible furnace and where large melts are not required.

The firm's latest design of large capacity brass melting furnace is shown in Figs. 2 and 3; it consists of a resister and container of trough form, with special ends on to which the water cooled electrodes are clamped.

The trough has a capacity of 800 lb. of brass and is provided with a pouring spout which ensures that the metal is drawn direct from the bottom of the trough and therefore clean. The crucible is embedded in a special insulating material and is backed by a lining consisting of the firm's special refractory insulating bricks. The whole is enclosed in a metal casing which has a rounded bottom, as shown in Fig. 3. In the furnace recently seen at the Battersea works the casing rested upon four rollers and was tilted into the pouring position by means of a worm and wheel, but in the commercial design the lip of the spout will be maintained in one position when pouring. To effect this the furnace will be tilted bodily about the spout, thus making it possible to pour direct into moulds arranged around a turntable or into a ladle on a trolley.

As the furnace is entirely encased, it is an easy matter to get rid of the fumes; the arrangements are shown on Figs. 2 and 3. A small suction fan is connected on to the outlet pipe at the top of the casing, and the discharge pipe is carried to the outside of the building. By these means fumes are not discharged into the foundry even when stirring or when pouring of the charge takes place.

The furnaces are at present suitable for temperatures up to 1,300 deg. C.; the heat efficiency is high. The power consumption is at the rate of about 15 kw. hours per 100 lb. of metal melted, but the firm hope to improve upon this figure as experience is obtained in the use of the furnace and care exercised in minimising the waste when the furnace is standing, being charged, or being poured.

In Fig. 4 is shown a special electrically-heated tube furnace in which the tube is the resister with the terminals, which are water cooled at the top and bottom.

The uses to which such a tube furnace may be put are many, especially as the size of the unit may be varied to suit reasonable requirements. The points to be taken into consideration when looking into the possibilities of the system are that due to the fine regulation of current possible, uniformity of heat, and therefore of heat treatment, may be secured, and that there are no gases or fumes to interfere with the process; in fact, the operation of annealing can be conducted in a vacuum, or gases of a special nature may be passed through the plant during the heating operation.

The main advantages of electrically-heated furnaces are the ease of control, cleanliness, no coke in the foundry, and which is a real boon to the employees; the atmosphere in the foundry is clear of fumes while, due to the small loss of heat by radiation, the foundry will be cool.

The furnaces and tubes can be run on either an alternating current or direct current system, and the voltage required at the furnace may be taken at about 40 volts. Thus, provided that arrangements can be made for the supply of electricity at a cheap rate the use of electrically-heated crucibles and furnaces will be extended. The curves in Fig. 5 show the electric power taken by a crucible furnace of the type shown in Fig. 1. They are reproduced from actual recorder charts and are both very interesting and instructive. The recorder paper was travelling at the rate of 3 in. per hour and the voltage and current can be read off for the melts specified.

We hope on a subsequent occasion to give more complete particulars of these furnaces, together with the results of working them on commercial lines.

THE INDUSTRIAL RECONSTRUCTION COUNCIL.—The following series of lectures have been arranged to take place at the Institute of Journalists, 2 and 4, Tudor-street, E.C. 4: April 1, (1) "The Determination of Standards in Scientific Management"; April 15, (2) "The Planning Department in Scientific Management"; April 29, (3) "Incentives to Efficiency in Scientific Management"; May 13, (4) "Costing in Relation to Scientific Management"; May 27, (5) "The Relation of Welfare Work to Scientific Management"; June 10, (6) "The Benefit to the Workman of Scientific Management." There will be a different speaker at each lecture. Each lecture will begin at 5.30 p.m., and be followed by a discussion. No tickets are necessary.

LOUGHBOROUGH TECHNICAL COLLEGE.—We have received from this Institution a report of a Conference, held at the college on the 14th ult., between over 100 delegates representing the British engineering industry, and a number of educational, municipal and labour authorities, to decide whether the instructional factory, established and successfully conducted during the war, should be continued under peace conditions. The factory, it was stated, was practically a complete engineering works of a very comprehensive character, covering the entire range of mechanical engineering from the foundry to the inspection department; with full equipment for testing, estimating, costing and purchasing. It was capable of accommodating some 500 students, and its object was to give theoretical and practical training upon a productive scale and, as nearly as possible, under manufacturing conditions. For its successful operation it needed the support and co-operation of the engineering industry. The support required, however, was not direct financial assistance, but the granting of contracts for manufacturing work, and the offering of works scholarships tenable at the Institution. At the Conference, after discussion, resolutions approving the objects of the Institution, and recommending the appointment of representatives of the industry to act in an advisory capacity to the governors in the administration of the Works Department of the college, were carried. A further resolution recommending engineering employers to consider the possibility of giving support to the scheme on the lines indicated above, was also carried.

SURVEYORS AND EXCESS PROFITS DUTY.—The Council of the Surveyors' Institution have been in correspondence with the Inland Revenue as to the liability of surveyors to excess-profits duty. They have from the first taken up the attitude that surveyors were exempted from liability under Section 39 of the Finance (No. 2) Act, 1915, in which view they were supported by the opinion of eminent counsel. The position, however, was complicated by the circumstance that persons practising as surveyors not unusually combine other forms of business such as engineering, architecture, auctioneering, &c., with their more purely professional work, and the Inland Revenue authorities claimed that commissions payable in respect of sales of property and the collection of rents were not exempted from liability. At a conference arranged with the Commissioners, in which representatives of the Auctioneers and Estate Agents' Institute took part, it was pointed out that a large portion of the remuneration in respect of the above descriptions of work was payable for purely professional services, such as were covered by the exemption in the Act. While still holding the view that the Act was not intended to apply to any form of business commonly carried on by a surveyor, the representatives of the two bodies agreed that to secure a settlement of the question, in view of the temporary nature of the duty, and the difficulty of obtaining a decision in the courts which would be generally applicable to all cases, it would be advisable to accept the compromise referred to in a letter from the Board of Inland Revenue, to the following effect:—"The Board of Inland Revenue are prepared to admit claims that in computing the liability to excess-profits duty of surveyors, auctioneers, &c., the receipts of the business, so far as derived from remuneration in respect of sales of land, including advice, &c., upon the sale and in respect of rent collection combined with estate management, should be regarded, except in cases where such a course is manifestly inequitable, as attributable equally to professional and non-professional work; and that the moiety of such receipts, which is attributable to work of a professional character, should be excluded from the computation of liability throughout, both in pre-war and accounting periods alike."

THE CORROSION OF METALS.

*Fourth Report of the Corrosion Committee of the Institute of Metals.**

By GUY D. BENGOUGH, M.A., B.Sc., and O. F. HUDSON, A.R.C.S., D.Sc.

THE report is divided into three main parts. The first is devoted to the question of the nature of the actions that take place when metals such as zinc, copper, aluminium, and alloys such as 70 : 30 brass, corrode in neutral or nearly neutral liquids, *e.g.*, distilled water and sea-water. The second section is devoted to the consideration of the behaviour of condenser tubes in similar liquids, and the variations in behaviour in different samples of tubes of nominally the same composition. In the third section an attempt is made to set out in some detail a statement of the practical problems of corrosion, which appear to the authors to be very different from what is usually supposed. A preliminary account is also given of experiments carried out with the object of testing an electrolytic (the Cumberland) process of protection. A pre-oxidizing protection process is briefly described.

PART I.—THE NATURE OF CORROSIVE ACTION.

The current theories of corrosion are briefly considered. The difficulties in the way of making a true quantitative determination of the amount of corrosion are discussed, and shown to be almost insoluble in certain cases with existing methods of analysis. Mere "loss of weight" measurements, unsupported by detailed analyses of scale and metals in solution, are considered to be of little value in many cases, and might be replaced with advantage by microscopic work.

The action of distilled water on metallic zinc has been studied in some detail, and the following conclusions have been reached. Metallic zinc is normally covered with a partially protective scale, which consists largely of oxide or basic carbonate. Water containing CO_2 can attack or dissolve the oxidized layer, and zinc can then be found in solution as a slightly soluble bicarbonate. The attack on the scale begins at certain points, and a true metallic surface is exposed to the action of the water. At such places a peculiar form of oxide is formed on the surface of the metal. Probably this oxide contains zinc peroxide, and exerts a catalytic action on the underlying metal. It is slightly soluble and passes into solution, and is afterwards largely percipitated as the ordinary hydroxide and carbonate. The precipitated hydroxide has a distinctly protective action on the metal beneath it, and reinforces the original scale and enables it to resist the action of CO_2. The action is thus localised. In the presence of very large amounts of CO_2, as, for instance, when the water is kept saturated by bubbling CO_2 through it, the products of corrosion are largely kept in solution and local action is almost entirely avoided, though the total amount of corrosion that takes place is increased. This is due to the fact that almost the whole of the original scale is removed by the solvent action of the water, with the result that further oxidation of the metal can take place, and further solution.

In the case of very dilute acid, such as acetic, the action consists in the replacement of hydrogen by zinc, but the action is not severely localised as in the case of distilled water; there are no local accumulations of the products of corrosion, and consequently the action is much more nearly uniform. There is no evidence that dissolved oxygen can act as a depolariser; hydrogen is given off as gas. The authors come to the conclusion that the initial action of distilled water on zinc is a process of chemical oxidation rather than electro-chemical displacement. The action of sea-water on zinc is also chemical rather than electro-chemical, and local action in this case also is due to the local accumulation of certain products of corrosion. The action of distilled water on copper is also chemical oxidation. There is no preliminary electrolytic action, even in the case of a surface of metallic copper known to be free from oxide previous to immersion. The oxide formed over the general surface immediately after immersion is a lower oxide, either Cu_4O or Cu_2O. In course of time it becomes further oxidised at irregularly distributed spots, and the product thus formed does not protect the underlying metal from oxidation to the same extent as does the original tarnish layer. The dark oxidation product itself, which is probably a cupric hydroxide or basic carbonate, tends to flake off the metal, probably owing to the formation of bulky oxidation products beneath it. The latter are porous, and apparently amorphous, and probably act catalytically by increasing the rate of oxidation of the underlying metal. The amorphous oxide is slightly soluble, but is finally precipitated from solution as crystalline cuprite, which has a lower solubility than the amorphous oxide. The result of the action, continued in time, is to cause shallow pits in the metal. Such pits are much less important than in the case of zinc. In the case of some further experiments, however, this pitting action was not developed, and the only action that could be observed was the formation of thick layers of oxide over the whole surface of the metal. These layers do not necessarily remain of uniform thickness over the whole surface of the specimen, but pronounced local action does not occur. In rare cases appearances are found on metallic copper, which the authors have only been able to interpret on the assumption that they are little electrolytic cells,† but the phenomenon is so rare that it is unimportant in comparison with the main action already described.

The principal action of sea-water on copper is again one of chemical oxidation. The action may be localised by the accumulation of products of corrosion, under certain conditions.

It has been found that the aeration of one of a pair of copper electrodes causes that electrode to be slightly electro-positive to the other. The effect on the rate of corrosion of the E.M.F. so set up was, however, found to be quite small, and less than the effect of other physical factors, such as the rate of flow of the corroding medium and the degree of aeration. The conclusion has been formed that differences in the rate of oxidation have a greater effect on the amount of corrosion than small differences of potential.

A number of experiments have been made on the effect of coupling together electrodes of different metals, and immersing them in different electrolytes. The behaviour of such couples was by no means always such as would be expected from electrode potential lists. In some cases the couple behaved in the reverse way to that which was expected, and in others the effect of the couple in increasing corrosion was much less than expected. The effect of a couple is greatly decreased if the contact between the electrodes is not very carefully made. It is probable that the effect of couples in some of the practical problems of corrosion has been over-emphasised rather than the opposite, as sufficiently good contact for large effect does not usually occur. It has been definitely established that a metal may be oxidised and pass into solution in spite of the fact that it has been continuously maintained as a cathode, and the laboratory result has been confirmed on the practical scale by experiments carried out with an electrolytic protection of condenser tubes (the Cumberland process).

A preliminary study of aluminium and certain light alloys in distilled water and sea-water has been carried out. Local severe pitting at or near the water-line is described and discussed. It is shown to be due to the presence of a strongly acid salt.

An attempt is made to introduce a definite system of nomenclature into the terms used in the study of the corrosion of binary alloys, in order to avoid the confusion which at present obtains. In certain cases precise definitions cannot yet be formulated, as in the case 70 : 30 brass, owing to the difficulty of distinguishing between residual metal and redeposited metal.

The nature of the action of distilled water on 70 : 30 brass has been studied in detail by means of the microscope and analytical methods. The action is considered to be the chemical oxidation of the copper and zinc, and the partial solution of the oxidised products. Much of the zinc passes into solution, in the presence of CO_2 and part of the copper, the remainder of both metals remaining on the surface of the alloy as an oxide scale. The scale becomes further oxidised and altered at certain spots which become covered with thick deposits of the products of attack. Such deposits are porous and allow, and probably accelerate, local attack on the underlying metal. The attack is accompanied by redeposition of copper by displacement by the zinc either electro-chemically or otherwise, and precipitation of cuprite. There are signs of slight local dezincification at such places, but the attack over the general surface of the alloy is complete corrosion. The positions at which local attack and pitting take place are not determined by the variation in the electrical properties of the original metal, but by the conditions of the experiment. In the presence of dilute acids, such as HCl and H_2SO_4, local action of the type described does not occur, since there is little or no local accumulation of oxidation products. On the other hand, the absence of CO_2 retards the action. From the analytical data it appeared that the local action in the case of distilled water increased with time, while the rate of general corrosion over the whole specimen fell off. These facts suggest the fallacy of loss of weight tests, since local action is more important practically than general corrosion.

The action of sea-water on brass has been studied on the same lines as that of distilled water. The action is considered to be similar in type. Local pitting and dezincification are due to the accumulation of the products of corrosion. Under certain conditions redeposition of copper may occur. The rate of general corrosion is much greater than that in distilled water, and does not fall off so rapidly with time. At the ordinary temperature there is less tendency to local dezincification.

PART II.—THE CORROSION AND PROTECTION OF CONDENSER TUBES.

The form of the surface of certain condenser tubes of 70 : 30 brass has been studied in detail. The presence of a layer that differs in its behaviour towards corrosive agents from the underlying metal has been identified in several different ways. In many cases this layer is probably richer in copper than the alloy beneath it. In such cases the tube may resist dezincification in a marked degree for long periods; in other cases the surface layer probably has nearly the same composition as the rest of the tube, and in such cases strong dezincification may take place in sea-water in the neighbourhood of 50 deg. C. Tubes from the same batch of manufacture usually resemble one another as regards the nature and properties of the layer, and tubes from different batches, even though made by the same maker, may differ. Thus one important factor as regards dezincification is the nature of the tube, but the kind of surface that best resists dezincification does not necessarily best resist other kinds of attack. Means of controlling the surface layer have not yet been worked out, but the problem does not appear to be insuperable, and is receiving attention. The condition of the surface layer should be adapted to the conditions under which the tube will be used.

In many cases local action may be initiated on condenser tubes by the action of certain bodies, which themselves appear to take no direct part in the action. Such bodies are sand, calcium carbonate, ferric hydrate, glass, clinker, and coke. The amount of action that takes place varies with the physical properties of the substance. The action is associated with the accumulation of products of corrosion, and may be largely assisted by them. The nature of this action is of well-marked type, and has been provisionally called oxide disintegration. It is usually characterised by intercrystalline oxidation. Actions of this kind are of great importance in many cases of corrosion on the practical scale.

A preliminary study has been made of the action of very dilute acids on copper, 70 : 30 brass, and Admiralty alloy. The matter is important technically, because supplies of water in certain parts of the country are

CAUSES OF CONDENSER TUBE AND FERRULE CORROSION. (WATER SIDE ONLY CONSIDERED.)

Cause.	How Produced.	Nature of Action.	How to be Remedied.
A. Foreign bodies carried in and accumulation of products.	A1. By ferric hydrate flakes from water ends. A2. By ashes, clinkers, &c. A3. By sludge of sorts in water supply.	Complete corrosion of the oxide disintegration type, causing local action.	A1. Paint the pipe line and water ends. Increase water speed. A1, A2 and A3. If worth while trap the water supply or pass it through a screen. In some cases increase water speed.
B. Acid or other bad or variable water supply.	B1. Some river supplies, *e.g.*, Tyne B2. ,, canal supplies, *e.g.*, ship canal B3. ,, well supplies. B4. ,, estuarine supplies. B5. ,, cooling tower arrangements.	Complete corrosion and rapid general thinning. Sometimes slight uniform dezincification.	Keep water supply slightly alkaline. Use special tubes adapted to the special conditions.
C. Temperature in condenser too high.	C1. Hot inlet water, *e.g.*, tropical. C2. Slow water speed. C3. Partial blocking of tubes.	C1. Dezincification. C2. Dezincification. C3. See A3.	C1 and C2. Use special tubes. C2. Increase speed. C3. See A3.
D. Undue aeration.	D1. Errors in pump and pipe line arrangements. D2. Eddies near inlet causing water-line effect.	D1. Complete corrosion of oxide disintegration type. D2. Complete corrosion of pitted areas.	D1. Remedy air leaks, &c. D2. Special ferrules. Possibly increasing speed of water with modified design of water end.
E. Unsuitable composition of tube.	E1. Zinc or impurities in too great amount. E2. Surface of tube not sufficiently copper-rich.	E1. Varies. E2. Dezincification.	E1. In manufacturing. E2. Probably by attention to details of annealing and pickling during manufacture.
F. Defective packing of tubes.	F1. Leaks caused by perishing of the packing material, especially in acid water. F2. Collapsing of tube.	F1. Varies. F2. ,,	F1. Use good tape packing. Red lead is sometimes useful to prevent leakage. F2. Do not crush tube when inserting it
G. Physically bad surface of tube; *e.g.*, bad spills and laminations.	G1. Foreign bodies caught and trapped which would otherwise be swept away.	G1. Complete corrosion and oxide disintegration.	G1. During manufacture.
H. Thermo - electric action in condenser.	H. By steam impinging directly on tubes, or being improperly distributed.	H. Dezincification.	H1. Only occurs in condensers of old design when steam is not properly distributed.
I. Too slow water* speed	I. Gases given off inside tube and not immediately swept away.	I. Complete corrosion near inlet end.	I. Increase speed of water. Do not use main condenser for auxiliary machinery import.

* See article by W Ramsey, ENGINEERING, July 17, 1917.

* General summary forming conclusion of paper read before the Institute of Metals on March 25. The report itself extends to so great a length that it is not possible to publish it *in extenso*.

† These appearances are only found after oxidation to dark oxide, &c., and not in the earlier stages of corrosion.

slightly acid in character. The strength of acids used were between 5 and 10 parts of acid in 100,000 of water. Both HCl and H_2SO_4 were used. Acids of these strengths greatly accelerate corrosion and alter the type of action. The attack of the two acids, even when of equivalent strength, differs both in extent and character, that of HCl being greater and more selective. Admiralty condenser tube was decidedly more resistant than 70 : 30 brass to the action of dilute acids.

PART III.—NOTES ON PRACTICAL PROBLEMS OF CORROSION.

Part III of the Report deals with the subject of corrosion under practical conditions as it appears to the authors. The views expressed are founded upon their general experience both in the laboratory and in connection with working conditions of actual plants. Unfortunately, the conditions in a practical plant are never known in full detail. Evidence as to the cause or causes of corrosion usually rests on a comparison of the corroded tube with others which appear to be similarly attacked under conditions that are more precisely known.* The degree of probability, therefore, which attaches to these views must be regarded as lower than that based on conclusions drawn from laboratory experiments.

The authors express the view that corrosive attack on condenser tubes is more diverse in character and complicated in nature than has been generally supposed. The first action is one of chemical oxidation, and secondary actions are of great importance. No one single remedy is likely to be found effective for all the different kinds of attack which occur in practice. The nature of the tube used and the protective measures chosen should be dependent on the particular set of conditions.

The following is a set of conditions under which a 70:30 brass condenser tube should have a minimum life of 20 years :

(*a*) Only clear water to enter the tube, or water which will not deposit suspended matter.

(*b*) The water must be free from gases in suspension, and must not contain more than the normal amount of air in solution.

(*c*) The water must be neutral or not more than very slightly alkaline. It must be free from ammonia and certain other specially harmful substances, which are, however, of comparatively rare occurrence in technical waters.

(*d*) The temperature of the cooling water in the hottest part of the condenser should not exceed 35 deg. C.

(*e*) The speed of the water should be about 5 or 6 ft. per sec.

(*f*) The steam should be properly distributed in the condenser, according to the best modern practice.

A water supply which varies considerably in composition at different times of the year involves special problems and must be excluded from the above statement at present.

In practice tubes fail sooner than the period stated, because the normal slow roughening of the tube by chemical oxidation is locally speeded up by factors which are for the most part independent of the tube. It will be noticed that this way of treating the subject is the inverse of that usually adopted. A preliminary attempt is made to gather the more important of these factors into a tabular statement, given on the preceding page. The statement is to be regarded as a skeleton structure, which will be emended and filled in as experience accumulates.

In practice factors set out separately in the table may act jointly. Causes of corrosion are not arranged in the table in order of importance, since this order varies in different types of installation. The effect of water speed on the rate of corrosion is briefly discussed ; its effect varies with the type of corrosion.

The effect of the presence of a scale on the rate of corrosion is considered to be of great importance. Of the substances that commonly occur in scale calcium carbonate is one of the most important. Its effect varies with its physical condition. It may exert almost any kind of effect from a considerable degree of protection to a serious attack.

Some observations are described on the effect of a form of electrolytic protection (the Cumberland process) at the Southwick Power Station of the Brighton Corporation, which is under the charge of Mr. J. Christie, who has placed many facilities at the authors' disposal. The conclusion is reached that the process ensures a prolonged life for the tubes under Southwick conditions, provided that it is applied to new tubes, i.e., to tubes that have not begun to corrode before the process is in operation. The process should be applied continuously and not intermittently. The authors consider that the thin uniform scale which is maintained on the tubes by the process is an important factor in preventing serious corrosion. One of the important functions of the scale is to prevent contact between the tube and harmful deposits and products of corrosion ; in addition it slows down, but does not entirely prevent, the general oxidation of the tube. The authors consider that further evidence is necessary before the value of the process can be estimated as regards prevention of corrosion in certain types of water other than ordinary sea-water, and in the presence of deposits other than those which occur at Southwick. Other possible methods of protection are briefly considered, and a preliminary account is given of a pre-oxidising process for reducing the rate of corrosion.

* Much of the evidence cannot be satisfactorily reproduced either photographically or by any other means known to the author. It is obtainable only by personal examination of tubes.

THE PROPERTIES OF SOME COPPER ALLOYS.*

By W. ROSENHAIN, B.A., D.Sc., F.R.S., Vice-President, and D. HANSON, M.Sc., Member (from the National Physical Laboratory).

DURING the past four years the Metallurgy Department of the National Physical Laboratory has been called upon to prepare a series of alloys of copper designed to meet certain special requirements. In the case of one group of these alloys it was considered desirable to avoid the use of zinc, while in the second group it was considered essential to avoid the use of aluminium or a high percentage of zinc. A considerable number of alloys have been prepared and rolled, and mechanical tests have been carried out upon them. Although the circumstances in which this work was carried out did not permit of a systematic investigation of the various alloy systems concerned, so that it cannot be claimed that the alloys described below are the best of their respective series, the data obtained in connection with them appear to be of sufficient interest to warrant publication. The present account of these alloys is therefore given for the purpose of placing at the disposal of workers in non-ferrous metals the compositions and mechanical properties of these materials, and of describing some of the difficulties met with in the preparation of these alloys, and the methods which have been adopted to overcome them.

It should be pointed out that the requirements which these alloys were intended to meet are of a very severe character, involving extensive cold-working, so that the alloys had to be capable of being rolled into thin sheet, which was required to have an excellent finish and to undergo further operations without cracking. A combination of high tensile strength with great ductility was therefore aimed at in every case.

The materials used throughout the work described in this paper consisted of electrolytic copper, high-grade aluminium (containing approximately 99·5 per cent. aluminium), and cupro-manganese (containing 30 per cent. manganese). The zinc employed was a high-grade material of American origin, an analysis of which showed the following results :—

	Per Cent.
Iron	0·0175
Copper	0·006
Lead	traces
Cadmium	traces

Nickel was used in the form of shot made by the Mond process.

SECTION I.—ALLOYS OF COPPER WITH ALUMINIUM, WITH MANGANESE, AND WITH MANGANESE AND ALUMINIUM, NOT CONTAINING ZINC.

Melting of the Alloys.—The copper was first melted down in a 60-lb. Salamander crucible under a layer of charcoal. As soon as this was molten the manganese was added in the form of cupro-manganese, and the temperature of the furnace was maintained until this was completely dissolved. The contents of the crucible were then well stirred and the aluminium added in the form of solid pure metal, the molten alloy being well stirred at the same time to ensure complete mixing. In some cases where the amount of aluminium to be added was not large an addition was made after the pot had been removed from the furnace and immediately before casting. There was, as usual, a marked rise of temperature on the addition of the aluminium. Before casting, the metal was carefully stirred with a graphite rod, the sides of the crucible being scraped to remove as much adhering dross and charcoal as possible. The metal was finally skimmed with great care with an iron skimmer coated with a wash of ganister in order to protect it from solution in the metal.

Casting.—The first method tried was that of casting the metal in the ordinary way by pouring it into pre-heated cast-iron moulds which had previously been dressed with blacklead paste. Even when the greatest care was taken in the casting process, and every endeavour was used to prevent the entrance of dross and small particles of charcoal into the mould, it was found difficult to obtain ingots with surfaces which could be regarded as satisfactory for the purpose in question. Slabs could be obtained which were quite sound and free from blowholes, but small particles of dross were frequently entangled in the surface, causing small imperfections which gave rise to slight spills and defects in the finished strip or sheet. As these interfered seriously with the desired uses of the sheet, it became necessary to avoid their occurrence.

A flux, consisting of cryolite, added after the metal had been taken out of the furnace, was tried. This proved partially successful, but even with its use it was not possible to secure perfect ingots with certainty and regularity. Another method was then tried.

Pressure Casting.—The defects noted above arose from the presence of foreign matter floating on the surface of the molten metal, and, in spite of every care, finding its way in small quantities into the mould. The obvious remedy seemed to be to cast the metal by tapping it from a point well below the surface, and the most satisfactory method of accomplishing this appeared to be a process sometimes known as "pressure casting," which has been developed and patented by Mr. F. Tomlinson of the Broughton Copper Company, Limited, Manchester. An adaptation of that method has been used with considerable success for dealing with these alloys. The principle of the method consists in forcing the liquid metal, by means of externally-applied air pressure, through a feeder tube communicating with the bottom of the mould and dipping into the molten metal nearly to the bottom of the crucible.

In order to carry this out it is necessary to use a previously-heated feeder tube, through which the metal can be forced without splashing and without exposure to the atmosphere, the dross, charcoal, &c., being left behind in the crucible. The amount of metal in the crucible must be so adjusted that the mould is filled before the bottom of the feeder tube is exposed, and the air pressure on the metal must be maintained until the ingot has become solid.

The apparatus used is illustrated diagrammatically in Fig. 1. A is a cylindrical cast-iron vessel, closed at the bottom, while the upper end is open and has an external flange. The crucible, C, stands on a fireclay support P. The top of the cast-iron vessel A is closed by means of a lid B, which is provided with an annular recess R, fitted with an asbestos washer for the purpose of making an airtight joint with the top of the vessel A, to which it can be tightly clamped by means of a number of screw clamps (not shown in the diagram). The centre of the lid is provided with a hole, 3 in. in diameter, into which fits a circular flange-piece of steel E, which is screwed to the iron tube D, ½ in. in internal diameter. This is the feeder tube, and its length is so arranged that it reaches nearly to the bottom of the crucible C. The steel-piece E, is separated from the lid by another asbestos washer, the object being to form an airtight joint and also to reduce the loss of heat from the tube D, to the cold lid of the vessel. The feeder tube and its holder are held in position by the clamping bar G, which consists of a flat strip of steel slotted in the centre to take the top of the tube, and near the ends to enter corresponding slots in studs H H. The clamping is performed by slipping the centre slot over the projection of the tube, and springing the plate until it is possible to engage the end slots in studs H H. The "spring" of this strip, together with the weight of the mould, are sufficient to hold the tube in place against the internal pressure in the vessel A. A two-part mould L, fitted with a hole in the bottom, fits over the projecting part of the tube D. The pressure vessel A is connected with a compressed air main through the inlet M, the supply being regulated by means of a delicate needle, valve ; an exhaust valve N is also fitted. A pressure gauge S is provided.

Casting Operation.—The requisite amount of metal is melted in the manner described above, except that it has been found convenient to add the aluminium while the crucible is still in the furnace ; this is done because it was found necessary, for this method of casting, to work at somewhat higher temperatures. When the last addition has been made the crucible is moved to one side of the furnace, and the feeder tube, with its steel flange screwed in position, is inserted into the furnace and left there until it has reached a bright red heat. The pot is then removed from the furnace, rapidly skimmed free from most of the charcoal and a little cryolite is thrown on to the surface. The crucible is then placed in the pressure vessel, the surface of the metal being again skimmed to leave the centre portion as clean as possible for the entrance of the feeder tube. The lid is then placed in position and clamped on. While this is being done the runner tube is taken from the furnace, placed in position and clamped. Then the previously-prepared mould is carefully lowered into place. During these operations the exit valve N is left open, in order to allow of the escape of the expanding air caused by the heating of the air in the vessel by the hot crucible, feeder tube, &c. As soon as the operations are completed this valve is first closed and then air is slowly admitted to the vessel from the compressed air main. The metal rises in the feeder tube and flows into the mould, the pressure of the air being regulated in such a manner that the mould is filled gently and without splashing. When the metal approaches the top of the mould the rate of flow is gradually reduced and is almost arrested, the last stages being carried out very slowly. At this stage a crust is formed on the top of the ingot. As soon as this is sufficiently thick, the pressure is gradually raised in the vessel to 30 lb. per square inch, and is maintained at that value until the ingot is solid. The pressure is then released, the clamping bar removed, and the ingot mould with the feeder tube attached is removed from the vessel. The liquid residue in the crucible can then be cast into small ingot moulds. The mould is then opened and the runner removed from the ingot by cutting off with a saw.

If suitable precautions are observed this process is eminently satisfactory, but it is necessary to use a fairly hot mould, since, otherwise, the metal is liable to be chilled in the narrow opening through which it has to pass, before the mould can be filled. Conditions should be so arranged that this orifice in the bottom of the mould remains open until the whole of the ingot is solidified. In the present experiments the mould was preheated in a special gas furnace in such a manner that the bottom of the mould was distinctly hotter than the top. The actual mould temperatures were of the order of 500 deg. C. to 600 deg. C. at the bottom.

It was found that as a rule a slight amount of shrinkage occurred at the top surface of the ingot ; this suggests that setting did not actually commence at the top, but at some point lower down. A slight amount of cropping was therefore necessary. Attempts were made to eliminate this by closing the top of the mould and forcing the metal up into contact with it. This gave an ingot of good external appearance, but there were signs that slight internal cavities had been formed. Such a defect is liable to give longitudinal unsoundness in the finished strip, and this device was therefore abandoned.

Used in the manner indicated this method of casting has given very successful results, all surface defects of

* Paper read before the Institute of Metals, on Tuesday March 25, 1919.

any kind being entirely eliminated. The size of the slabs produced was 14 in. by 7 in. by 1½ in.

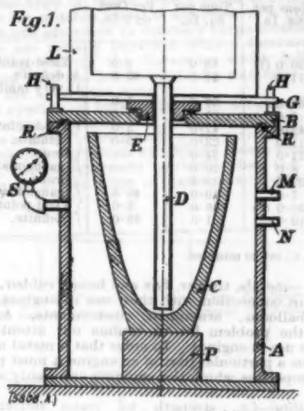
The composition of the alloys cast in this manner, together with the result of mechanical tests, are given in Table I. Before considering this table in detail, however, it may be well to mention a point in connection with the casting of manganese-copper alloys. Difficulty has been experienced with these on account of the readiness with which the surface becomes oxidised. Even during the short interval necessary for casting the alloy becomes covered with a thick black coating of oxide, which is liable completely to ruin the surface of the ingot. It has been found that the addition of 0·25 per cent. of aluminium prevents this oxidation and removes this defect entirely.

Rolling of the Alloys.—The rolling of these alloys has presented no difficulty whatever. They were broken down hot (temperature about 800 deg. C.) from a thickness of 1½ in. to about ⅜ in. The strips thus produced were pickled and then cold rolled to a thickness of 0·14 in. Some of the strips thus produced have subsequently been annealed and further cold rolled to a thickness of 0·04 in. The annealing of these alloys for the purpose of further cold-rolling can be conveniently carried out at any temperature between 500 deg. and 800 deg. C. A range of from 650 deg. C. to 750 deg. C. is convenient and satisfactory.

The alloys which contain manganese tend to become oxidised on the surface during annealing, and this oxide is somewhat adherent and difficult to remove. The pickling appears to be best done by dipping the alloy, while still hot, into hydrochloric acid of specific gravity 1·1.

cent. manganese (No. 6). After similar mechanical treatment both have been annealed for 30 minutes at 650 deg. C. It will be seen that the crystal size attained by the alloy (No. 6) containing manganese is very markedly smaller than that of the other alloy. It may be interesting to mention in this connection that similar observations as to the effect of manganese on rate of

Fig. 1.



studied by one of the present authors and Mr. S. L. Archbutt.

SECTION II.—ALLOYS FREE FROM ALUMINIUM.

The alloys of this group have been investigated at a different time from those described above. The conditions to be met with in this group required that no aluminium should be used in their manufacture, while the alloys themselves were required to withstand severe stamping and drawing operations in the form of thin strip less than one-twentieth of an inch thick. In the production of these alloys different casting methods have been adopted, and very much smaller ingots, 12 in. by 5 in. by 0·75 in. thick, weighing about 15 lb., have been used.

The pressure casting method described in connection with the previous group of alloys was not adopted because, in the first instance, alloys not described in the present paper were experimented with, whose very high melting-point made the use of an iron feeder tube impracticable. Subsequently, the methods of casting evolved for these high melting-point alloys were adapted and found satisfactory for the materials described below. It was found at the outset that it was difficult to obtain from metal melted under charcoal, ingots perfectly free from defects, however carefully the skimming operation was carried out before pouring. Particles of dross and charcoal could not be entirely eliminated, and gave slight surface defects, traces of which could be found on the finished strip. The addition of a little borax as well as charcoal was tried, with the object of preventing the formation of dross, but it was found impossible to skim the alloy quite free from borax, and

FIG. 2.—Alloy of copper containing 7 % of aluminium—cold rolled and annealed at 650°C. for 30 minutes. Magnified 150 diameters. Etched with copper ammonium chloride.

FIG. 3.—Alloy of copper containing 7 % of aluminium and 1 % of manganese—cold rolled and annealed at 650°C. for 30 minutes. Magnified 150 diameters. Etched with copper ammonium chloride.

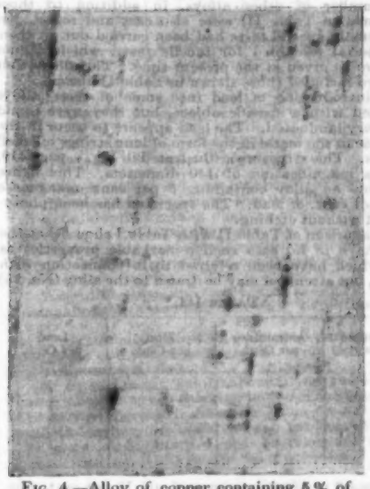


FIG. 4.—Alloy of copper containing 5 % of manganese and 1 % of lead—as rolled. Unetched. Magnified 150 diameters.

The results of tensile and Brinell tests on these alloys in the form of strip 0·14 in. thick are given in Table I. The Brinell tests, in view of the thin section of material available, have been made with a ball 5 mm. diameter and a load of 300 kg. Under these conditions the impressions are not very deep, but the results must be taken with the reservation which necessarily applies to Brinell tests on such thin material.

The results shown in Table I are remarkable for the very high degree of ductility which can be obtained, together with considerable tensile strength, by the use of aluminium or aluminium plus manganese. Probably the most remarkable result is that for the alloy No. 3 containing 7 per cent. aluminium without manganese, which in the "as rolled" condition attains a tensile strength only just under 40 tons per square inch, with an elongation of 17·5 per cent., while the same alloy after annealing still has a tensile strength of 27·5 tons per square inch, and the remarkable elongation of 71 per cent. The results for this alloy are closely approached by the alloy No. 6 containing 7 per cent. aluminium and 1 per cent. manganese, where the figures are 35·5 tons per square inch tensile strength, with 28 per cent. elongation in the "as rolled" condition, and 29·3 tons per square inch tensile strength, with 65 per cent. elongation in the annealed condition. Similarly remarkable results are given by the alloy (No. 8) containing 6 per cent. aluminium and 3 per cent. manganese. The results for the last two alloys in the table (Nos. 11 and 12) containing no aluminium are also interesting, although the figures are distinctly lower than for the alloys in which aluminium is present.

Microstructure.—In the annealed state all the alloys described in Table I consist of homogeneous solid solution. The chief point of interest with regard to their structure is illustrated in Figs. 2 and 3, above, under a magnification of 150 diameters. These photomicrographs show the effect of manganese in restraining crystal growth during annealing. The alloy represented by Fig. 2 (No. 3) contains 7 per cent. aluminium, while that of Fig. 3 contains 7 per cent. aluminium plus 1 per

TABLE I.—*Alloys of Copper with Aluminium and Manganese.*

No.	Chemical Composition. Aluminium.	Chemical Composition. Manganese	Condition of Alloy.	Yield Stress. Tons per Sq. In.	Ultimate Stress. Tons per Sq. In.	Elongation. Per Cent. on 2½ In.	Brinell No.
	p.c.	p.c.					
1	3	0	As rolled	26·6	26·8	9·0	137·5
			*Annealed	5·8	17·7	55·5	60·0
2	5	0	As rolled	34·3	35·1	16·5	174·5
			*Annealed	8·3	25·5	70·0	84·5
3	7	0	As rolled	38·7	39·8	17·5	195·0
			*Annealed	7·0	27·5	71·0	75·5
4	3	1	As rolled	26·2	26·8	11·5	141·5
			*Annealed	10·0	20·2	50·0	72·5
5	5	1	As rolled	28·7	31·1	27·0	162·5
			*Annealed	12·0	26·3	57·0	89·5
6	7	1	As rolled	34·1	35·5	28·0	184·0
			*Annealed	11·5	29·3	65·0	99·5
7	3	3	As rolled	27·3	27·7	12·0	140·0
			*Annealed	10·2	21·4	48·0	78·5
8	6	3	As rolled	38·2	39·0	12·0	—
			*Annealed	13·7	29·8	58·0	—
9	2	5	As rolled	29·6	29·9	9·0	145·0
			*Annealed	10·4	22·4	45·0	83·0
10	4	5	As rolled	35·0	35·7	15·5	182·0
			*Annealed	11·3	26·7	55·0	95·0
11	0	5	As rolled	29·3	29·3	9·0	149·5
			*Annealed	9·2	21·0	45·0	81·0
12	0	7	As rolled	29·4	29·4	8·5	182·0
			*Annealed	10·6	22·1	44·0	95·0

The figures given in the above table are mean values obtained from two test-pieces from each alloy. In no case was there any noteworthy disagreement between duplicate tests.

* The annealed test-pieces were heated at 650 deg. C. for half an hour and cooled in air.

crystal growth have been made in a light alloy of aluminium containing zinc and copper, which has been

some entered the mould, carrying a certain amount of charcoal with it. This spoiled the surface of the ingot.

Finally the alloys were prepared with the aid of borax alone. This was added with the first charge, and consequently melted before the alloy. The metal as it melts then runs to the bottom of the crucible and immediately becomes covered with a film of borax, which not only protects it from oxidation but dissolves any free oxide which is present. When the alloy is completely molten it is removed from the furnace and skimmed as well as possible before pouring. While the whole of the borax could not be completely removed from the surface of the molten metal, only a little entered the mould when the alloy was poured, and it was found that the borax, being much lighter than the alloy, floated to the surface of the metal in the mould, until the rising metal pressed the globular borax against the side of the mould, in which position it became fixed. As the borax in these circumstances is still fluid it becomes considerably flattened by the pressure of the metal, and on removing the alloy from the mould it was found that the borax fell away, leaving merely shallow depressions on the surface. On rolling, these slight depressions disappear completely during the first few passes, and are therefore without effect on the metal in its later stages.

By this method the alloys, particulars of which are given in Table II, were, among others, successfully cast into sound ingots which were subsequently rolled into strips free from surface defects of any kind.

Rolling of the Alloys.—The alloys were cold-rolled from the cast slab down to a thickness of 0·04 in. in the experimental rolling-mill at the National Physical Laboratory. All the alloys rolled with ease, and with one intermediate annealing at a thickness of either 0·375 in. or 0·15 in. gave strip free from edge-cracking. Some of the alloys were rolled cold from a thickness of 0·75 in. to 0·04 in., but edge-cracking appeared to a slight extent in the later stages. The most satisfactory strip was obtained by cold rolling from a thickness of 0·75 in. to 0·15 in., annealing at a temperature of 650 deg. C., and finishing cold to a thickness of 0·04 in.

TABLE II.—ALLOYS CONTAINING NO ALUMINIUM.

No.	Chemical Composition. Cu.	Mn.	Zn.	Ni.	Pb.	Condition of Alloy.	Yield Stress. Tons per Sq. In.	Ultimate Stress. Tons per Sq. In.	Elongation. Per Cent. on 2 In.	Remarks.
13	95·5	4	—	—	0·5	As rolled ..	30·0 (?)	38·0	4·5	Yield-points indefinite. Strip very laminated.
						*Annealed ..	11·0	21·0	35·0	
14	88·0	2	10	—	—	As rolled ..	35·0	37·0	5·0	
						*Annealed ..	8·0	21·0	41·5	
15	87·0	3	10	—	—	As rolled ..	42·0	47·0	3·0	Yield-points indefinite.
						*Annealed ..	11·0	23·0	35·0	
16	85·0	—	5	10	—	As rolled ..	31·0	34·0	—	Broke outside gauge marks.
						*Annealed ..	8·0	20·0	—	
17	88·0	—	7	5	—	As rolled ..	27·5	32·5	—	Broke outside gauge marks.
						*Annealed ..	7·0	19·0	40·5	
18	80·0	—	10	10	—	As rolled ..	35·0 (?)	39·0	3·0	Yield-points indefinite.
						*Annealed ..	10·0	21·0	35·0	

* Annealing was carried out at 650 deg. C. for 30 minutes.

The results of mechanical tests on a number of these alloys are given in Table II above :—

In addition to the tests described in the above table, a considerable number of other alloys were also submitted to a severe form of cupping test, and, with the exception of the alloy (No. 13) containing 4 per cent. manganese and 0·5 per cent. lead, were found satisfactory. The latter alloy (the first one of this table) is extremely laminated in the form of strip and is quite unsuitable for drawing and cupping operations.

A number of other alloys, in addition to those mentioned in Table II, were also cast and rolled, but after certain special tests had been carried out on them no material remained for tensile tests, which cannot therefore be given at the present time. The alloys thus prepared included those shown in Table III below.

The introduction of lead into some of these alloys was tried with a specific object, but they were found to be very laminated. The lead appears to occur in the free state in the metal in the form of long strings of small globules. This structure is illustrated in Fig. 4, page 419, under a magnification of 150 diameters. This figure represents an alloy containing 5 per cent. manganese and 1 per cent. of lead. The specimen has been photographed without etching.

A comparison of Table II with Table I shows that the alloys have in no case such remarkable properties as those which have been referred to in connection with Table I, but attention may be drawn to the alloy (No. 15)

TABLE III.

Manganese per Cent.	Aluminium per Cent.	Zinc per Cent.	Lead per Cent.
5	—	—	1
3	—	10	1
3	—	5	—
—	3	10	—
—	3	10	1

containing 3 per cent. manganese and 10 per cent. zinc, which, in the cold-rolled condition, has a tensile strength of 47 tons per square inch, with 3 per cent. elongation, and in the annealed condition a tensile strength of 23 tons per square inch, with 35 per cent. elongation.

The authors desire to acknowledge their indebtedness for much valuable help, in carrying out the considerable amount of experimental work which is represented by the results given in the above paper, to their colleague Mr. S. L. Archbutt, F.I.C., while they are indebted to Mr. F. Tomlinson, of the Broughton Copper Company, Limited, at one of whose mills the alloys described in Table I were broken down. The authors are indebted to the director of the National Physical Laboratory, Sir Richard T. Glazebrook, C.B., F.R.S., for permission to publish the present results.

ON THE METALLURGICAL INFORMATION REQUIRED BY ENGINEERS.*

By Lieutenant-Colonel C. F. JENKIN, R.A.F., M.A., M.B.E., Member (Oxford University).

FOR the past four years the writer has been responsible for recommending materials for all parts of aeroplanes and aero-engines. In engineering it has been customary to adhere to the use of materials which experience has shown to be suitable for the different parts, but in aircraft a new factor is of paramount importance—viz., weight—with the result that new materials, such, for example, as aluminium alloys, are constantly being suggested and tried for purposes for which they have never before been used. Further, it has become of importance to use all materials in their strongest condition; thus the bulk of the steel used is so treated as to have a strength about double that of the steel used for ordinary engineering work. In order to be able to judge whether a new material (or an old material in a new condition) is suitable for any particular use the following fundamental problem, therefore, becomes of essential importance :—

"On what properties of the material does its suitability for any particular purpose depend ?"

This question has arisen in connection with all sorts of materials—metals, timber, flax and hemp, rubber, paint, &c., and in connection with their use in engines, aeroplanes, balloons, armament, instruments, &c. To simplify the problem let us confine our attention to metals for use in engines. In order that a metal may be suitable for a particular part of an engine it must possess certain properties which the engineer can easily specify *e.g.* :—

1. *Stability—i.e.*, strength to resist deformation (beyond a minute extent).

2. *Long Life—i.e.*, endurance when subjected to stress (of a definite sort) and when subjected to abrasion and corrosion.

3. *Special Properties* for certain parts—*e.g.*, a low coefficient of friction for bearing metals.

For simplicity we may confine our attention to items 1 and 2. Stability and long life, then, are the properties desired by the engineer; but these are not among the properties which are known to the metallurgist, and when the engineer asks for information he is given a very different list of data, viz. :—

Chemical analysis.
Microstructure.
Mechanical tests—ultimate strength, elastic limit, elongation, reduction of area. Bend tests of different sorts. Brinell, scleroscope. Izod. Fatigue range.
Chemical reactions.

There is hardly any correspondence between the two lists. In an attempt to bridge the gap between the two we use a terrible list of vague words to hide our ignorance.

Hardness.
Springiness.
Toughness and brittleness.
Fibrous or crystalline structure.
Resistance to shock or vibration or impact.

Some comparison may be attempted between the two lists by putting them in parallel columns :—

Stability under tensile or compressive stresses ...	Elastic limit.
Stability under bearing pressure (rivet holes, pin holes, ball bearings)	Scleroscopic hardness. Brinell hardness. Resistance to scratching.
Life under steady stress ...	Elastic limit.
Life under varying stress ...	Fatigue range.
Life under abrasion	"Hardness" (one of the meanings).
Life under corrosion ...	The chemical reactions on which corrosion depends are little understood.
Of no interest to the engineer	Chemical analysis.
Of no interest to the engineer	Microstructure.
Little interest except as giving a margin of strength before final fracture in some steadily-stressed parts ...	Ultimate strength.
No interest	Elongation.
No interest	Reduction of area.
No interest	Bend test.
No interest	Brinell.
No interest	Izod.

To illustrate the want of correspondence between the two columns let us suppose that it is desired to replace steel by an aluminium alloy for some purpose. It is obvious that it is impossible to make any useful comparison by comparing the analyses or the microstructure of the two metals. It is really useless to compare the ultimate strengths, elongations, reductions of area, Brinell and Izod figures. For consider the elongation. Why do we specify 17 per cent. elongation for a steel crankshaft when $\frac{1}{2}$ per cent., if it occurred, would ruin it ? Is there any reason, then, to specify 17 per cent. elongation for an aluminium crankshaft ? These apparently important mechanical tests are really no more rational guides than, say, colour. As a matter of fact, an experienced eye can judge as well by the colour of the steel fracture as by the Izod figure of a fracture. But it is obviously useless to compare steel and aluminium by colour.

If the metallurgist's properties are so useless to the engineer, why are so many of them included in the specification ? Owing to the lack of knowledge about the life and stability of materials it is not possible to specify such qualities, and the engineer has to specify some definite material which he wishes to use, either for an experiment or as a result of former experience. For this purpose he uses the chemical analysis to define the material, and the microstructure and mechanical tests to define the condition of the material.

What, then, is needed to enable a satisfactory answer to the problem to be given ?

1. It is necessary to ascertain what physical properties of the metal they are which determine its behaviour under the conditions specified by the engineer.

2. It is necessary to determine tests which shall show the extent to which those physical properties exist in any metal.

3. The names for these properties must be accurately defined.

As an example, consider a crankshaft. It is suggested that the only properties which may need to be considered are :—

1. The fatigue range. The designed stress must not exceed this.

2. Freedom from sharp cracks or faults. Such faults may be due to casting flaws, or to a crystalline structure which encourages surface cracks during machining.

Wearing property may be found to be unnecessary with properly lubricated bearings—if not, this must be added to the list.

All the other properties enumerated on the previous page may be found to have no direct bearing on the suitability of a material for crankshafts. It may be gratifying to a steel maker to see a broken crankshaft twisted into all sorts of shapes after an accident—but why should it not have snapped off like glass ?

The above two requirements for a crankshaft may be referred to more elementary properties by the metallurgist. He may be able to indicate the types of solution or crystalline aggregate which are likely to give the desired results. If we could arrive at such a result it would be a great advance on our present position. Such complete solutions have been reached in a few cases, and are certainly not impossible.

As an example of a test properly designed to determine the required property, Strohmeyer's test for the fatigue range may be given. A little further research on this test will probably make it perfectly trustworthy. There is no doubt what it measures.

A satisfactory answer to the problem should not be beyond the reach of the metallurgist and engineer if they work in conjunction. The reason that former attempts have had such relatively unsatisfactory results, appears to be that engineers and metallurgists have not worked together, and that engineers have not fully realised the fundamental nature of the problems they were attacking.

It may be possible to correlate the essential engineering properties with the results given by existing types of test, and it is on these lines that most work has hitherto been done, but more probably new methods of testing will have to be devised. If new methods of testing are needed it is important that they should be designed to give the precise information required. Too many new tests have been devised in recent years without any exact knowledge of what their results signify. As a consequence a great amount of research has been expended in endeavouring to interpret the meaning of the new tests, which research would have been more profitably spent in devising tests to give the essential data.

* Paper read before the Institute of Metals, on Tuesday, March 25, 1919.

CHANCES OF LOSS OF MERCHANT SHIPS.*

By W. S. ABELL, Chief Ship Surveyor, "Lloyd's Register of Shipping."

THE enormous losses of merchant ships arising from the operations of enemy submarines have caused considerable attention to be directed to the question of watertight subdivision of such vessels. One method of obtaining increased protection is to provide additional bulkheads, which would materially prevent loss of vessel if the intactness were likely to be preserved. In view, however, of the considerable extent of torpedo damage in the longitudinal direction, it is obvious that there is an inferior limit to the spacing of the bulkheads below which the protection afforded is practically useless.

In addition to such objection, a close spacing of bulkheads materially increases the difficulties of loading and unloading, and consequently decreases the time-capacity of the vessel to transport goods.

The correct spacing to obtain the maximum efficiency of transportation must depend on a calculation of the probability of loss of one or more bulkheads, and of the consequent effect of the loss of these bulkheads on the ultimate chances of the sinkage of the vessel.

The first step to be taken is to obtain an approximate estimate of the chance of loss of bulkheads, and for that purpose it may be assumed that the intactness of watertight subdivision will be destroyed within some radius R of the centre of explosion of a torpedo. The great majority of cargo steamers can only be provided with vertical transverse bulkheads, and consequently it is only necessary here to consider the aspects of the case where R is a horizontal distance from the centre of explosion.

Case I. *Spacing* $> 2R = (2R + a)$.

If the explosion occurs at a distance, R, from the bulkhead, the intactness is destroyed, and consequently within a space $(2R + a)$ bounded by a bulkhead at each end, the horizontal length wherein the vessel may be hit without damaging a bulkhead is a, and the length where the contrary effect is produced is 2R.

The "odds on" for loss of a bulkhead are therefore $2R/a$.

The properties of the curve $2R/a$ are simple, and when

* Paper read before the Royal Society, January 22, 1919, and reproduced by permission.

$2R + a$ is great compared to $2R$ the "odds on" loss are small. As the value of $2R + a$ decreases, the "odds on" rapidly increase until, where the spacing is within about 15 per cent. greater than $2R$, the rate of increase of odds is extremely rapid. When the spacing is very nearly $2R$ the "odds on" for loss of one bulkhead are, of course, very nearly infinite. It is therefore important that the spacing of bulkheads shall be greater than $1{\cdot}15 \times 2R$, in order that the probability of loss shall not be largely and unduly increased.

Case II. *Spacing* $< 2R = (2R - a)$.

In this case one bulkhead will be damaged in every instance, and it is now necessary to calculate the chances that two bulkheads will be destroyed by one explosion. Considering the space $(2R - a)$ bounded by a bulkhead at each end, the length wherein two bulkheads will be damaged must be the space which is at, or less than, R ft. from either bulkhead. The length of this danger region is obviously a, and the remaining length is $(2R - 2a)$; consequently, for the loss of two bulkheads the "odds on" are $a/2R - 2a$.

The variation of this relation is generally similar to the previous one, except that when the spacing is $= 2R$, or $a = 0$, the "odds on" loss for two bulkheads is zero. On the other hand, when a approaches R the "odds on" loss approach infinity: in fact, as in the previous case, it is desirable to avoid spacing of bulkheads lying between $1{\cdot}15$ R and R in order to confine the probability of loss to reasonable limits.

Case III. Spacing $<$ R $=$ (R $-$ *a*).

It is obvious, apart from the resistance offered by a bulkhead to distortion under the effects of an explosion that whenever the spacing is less than R, two bulkheads are rendered ineffective. Case III resolves itself into a calculation to determine the probability of damaging three bulkheads. By similar reasoning to that previously adopted, it will be seen that within a region, a, on each side of a bulkhead, it is possible to destroy three bulkheads. Consequently, since the remaining space is $(R - 3a)$, the "odds on" for loss of three bulkheads are $2a/R - 3a$.

The form of this fraction follows the same general nature as the previous case, and is subject to the same approximate limitation that spacings between $1{\cdot}15(2R/3)$ and $2R/3$ should be avoided.

Application of Results to Actual Vessels.

As the conditions of flotability vary considerably with the type of vessel, which again is related to the service for which a vessel is designed, it is preferable to confine our attention to ordinary cargo steamers. Such vessels are usually provided with a forecastle, bridge and poop, and in the discussion which follows, it is assumed that the freeboard is the minimum permitted under the Load Line Acts.

The spacing of bulkheads, in an actual ship of given dimensions, draught, and type, is dependent on the nature of cargo carried and on the permeability, i.e., the amount of water which will fill the spaces unoccupied by cargo. It is extremely probable that the conditions obtaining at the time of damage will differ radically from the assumptions made, and there will be in general an increased risk of loss arising from such difference.

The "floodable length," or the length which may be flooded without loss of ship under assumed conditions of loading and of permeability, bears a fairly constant relation to length of vessel, since the type is fixed. The floodable length necessarily varies throughout the length, being greater at the ends and amidships than it is in the forward and after holds; the approximate minimum values of the floodable length have therefore been taken, since these values will give the maximum probability of loss.

In vessels of the ordinary cargo type the permeability, coefficient of fineness of form, and ratio of sheer of the bulkhead deck to length are practically constant for varying length of ship. The minimum freeboard permitted by the Load Line regulations varies so that the ratio of freeboard to draught actually increases with length of vessel.

The minimum floodable lengths are obtained from the Board of Trade standard curves, which give the percentage of length which can be flooded in terms of coefficient of fineness of form, ratio of freeboard to draught, and ratio of sheer of bulkhead deck to draught. These minimum floodable lengths when plotted on a base of length of ship lie approximately on a straight line.

When the bulkheads throughout a ship are so spaced that any one compartment can be flooded and the ship remain afloat, the flotability is defined as a "one-compartment" standard. When the arrangements are such that any two adjacent compartments can be flooded without loss of vessel, the standard is designated "two-compartment," and a similar notation is given to higher degrees of subdivision. Such definitions necessarily imply that the bulkheads bounding the flooded space remain intact.

Since the damage inflicted by a torpedo explosion is limited in extent, it is evident that the larger the vessel the greater the floodable length and the greater the chance of remaining afloat after a hit. On the other hand, starting from a "one-compartment" standard where the spacing of bulkheads is the floodable length, and where the loss of one bulkhead means the sinkage of the vessel, it is obvious that the chances of damage of a bulkhead, i.e., the chances of loss of vessel, continuously increase as the bulkhead spacing diminishes. The risk of loss from torpedo explosion therefore increases very rapidly until a "two-compartment" standard is obtained.

With the type and freeboard assumed the "two-compartment" standard can only be obtained in two ways:—

1. By building ships of such size that the floodable length is somewhat in excess of twice the diameter of the explosion circle; or

2. By increasing the freeboard, and thereby deliberately sacrificing the carrying power of the vessel, in order to provide increased protection.

The further discussion of the subject will probably be more intelligible if figures be taken for the various quantities involved.

Numerical Results.

The value of R, the radius of damage from a torpedo explosion, has to be assumed, and for the purposes of the argument it is desirable to keep the estimate on the large side. Experience indicates that R = 20 ft. would be a good approximation.

Fig. 1 illustrates the "odds on" for loss of one, two and three bulkheads, expressed as ordinates on a base of bulkhead spacing. This diagram shows the desirability of avoiding spacings which lie between 40 ft. and 47 ft., 20 ft. and 23½ ft., and 13½ ft. and 15 ft. for the one, two and three bulkhead losses respectively.

Fig. 2 is a scale diagram giving the approximate relation between "floodable length" and "length of vessel" for a cargo steamer, with forecastle, bridge and poop of normal extent, with the minimum freeboard permitted by the Load Line regulations.

Fig. 3 is obtained by combining the results of Figs. 1 and 2, and gives as ordinates the "odds on" for loss of vessel, i.e., the "odds on" for loss of one bulkhead for a "one-compartment" ship, two bulkheads for a "two-compartment" standard, and three bulkheads for a "three-compartment" vessel.

The following deductions may be drawn:—

1. Decrease of size of a large vessel only slightly increases chances of loss. In a "one-compartment" ship, where the bulkhead spacing is equal to the floodable length, the "odds on" for loss of vessel are 1 to 1 for a vessel 460 ft. in length, and about 2 to 1 for a length of about 385 ft. With a "two-compartment" standard, the "odds on" for loss are practically "nil" at about 460 ft., although, owing to the limitation of spacing already mentioned, the length of ship should preferably be nearer 500 ft.

For vessels of length of about 340 ft. and below, the risk of loss of ship is relatively high, and with very little diminution in length the "odds on" for loss increase very rapidly. From the diagram, ignoring the resistance afforded by a bulkhead to distortion under torpedo explosion, it is extremely doubtful whether any subdivision by transverse watertight bulkheads, however great, is likely to be effective when the length of the vessel is about 320 ft. or less than that amount.

3. As illustrating the increase of safety arising with the larger vessel it may be observed that:—

(*a*) A vessel of 460 ft. length with the "one-

Fig. 1.

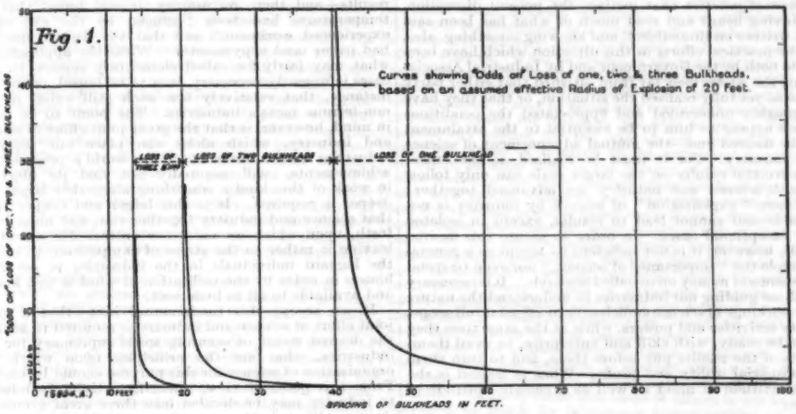

Curves showing Odds on Loss of one, two & three Bulkheads, based on an assumed effective Radius of Explosion of 20 Feet.
LOSS OF THREE BULKHEADS
LOSS OF TWO BULKHEADS
LOSS OF ONE BULKHEAD
"ODDS ON" LOSS OF ONE, TWO & THREE BULKHEADS
SPACING OF BULKHEADS IN FEET.

Fig. 2.

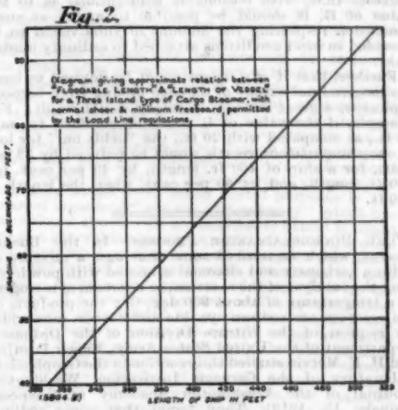
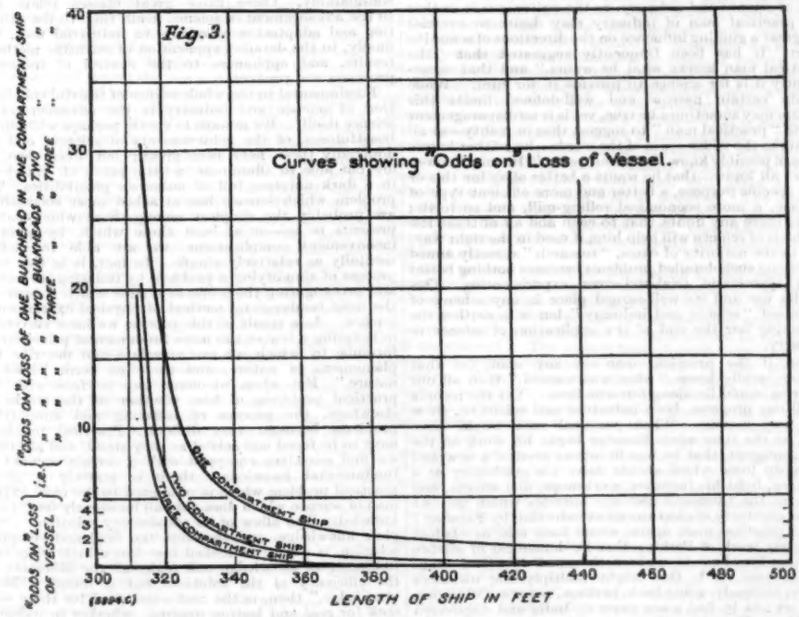


Diagram giving approximate relation between "FLOODABLE LENGTH" & "LENGTH OF VESSEL" for a Three Island type of Cargo Steamer, with normal sheer & minimum freeboard permitted by the Load Line regulations.
SPACING OF BULKHEADS IN FEET.
LENGTH OF SHIP IN FEET

Fig. 3.


Curves showing "Odds on" Loss of Vessel.
"ODDS ON" LOSS OF ONE BULKHEAD IN ONE COMPARTMENT SHIP
TWO BULKHEADS " TWO
THREE " THREE
"ODDS ON" LOSS OF VESSEL
i.e.
ONE COMPARTMENT SHIP
TWO COMPARTMENT SHIP
THREE COMPARTMENT SHIP
LENGTH OF SHIP IN FEET

compartment" standard is as safe as one of 360 ft. length subdivided on the "two-compartment" system.

(b) A vessel of 500 ft. length with bulkhead spacing equal to floodable length is as safe as one of 345 ft. length with bulkheads arranged for a "three-compartment" standard.

4. The effect of the adoption of intermediate bulkheads in a one-compartment ship (in order to comply with, say, the two-compartment standard), varies considerably with the length of vessel. Whereas, in the 500-ft. vessel the two-compartment standard is practically immune as compared with the one-compartment, yet at 340 ft. length the three-compartment vessel is only twice as safe as the two-compartment system, and the latter is only 2½ times as safe as with the one-compartment standard. In addition, spacing of intermediate bulkheads should avoid more particularly the dangerous limits such as 20 ft. to 23½ ft. already mentioned.

General Remarks.

The discussion of this particular phase of the problem suggests that, with reasonable assumptions as to the value of R, it should be possible to arrive at some conclusion respecting the amount of subdivision to be provided to meet conditions attached to ordinary marine risks.

Further, that if any means could be devised to limit the longitudinal extent of damage arising from torpedo explosion, a great increase in safety would result. For example, if the value of R could be confined to, say, 16 ft., as compared with 20 ft., the "odds on" for loss of one-compartment vessels would be reduced by 33 per cent., for a ship of 460 ft. length, by 40 per cent. for 400 ft. length, and by 60 per cent. when the length is 340 ft.

THE BUCHER CYANIDE PROCESS.—In the Bucher process, which we noticed some time ago, a mixture of sodium carbonate and charcoal is heated with powdered iron, the catalyst of the reaction, in a stream of nitrogen, to a temperature of about 900 deg. C.; the products of the reaction are sodium cyanide and carbon monoxide. By request of the Nitrate Division of the Ordnance Department of the United States Army, Eugen Posnjak and H. E. Mervin studied this reaction in the Geophysical Laboratory of the Carnegie Institution, Washington (Journal of the Washington Academy of Sciences, January 19, 1919). They found that some sodium cyanide was formed, but that the crude technical product consisted mainly of some other similar substance. They relied chiefly on optical tests as being relatively simple. According to Bucher the cyanide can be obtained from his crude briquettes by distillation at 800 deg., or even lower temperatures; this is not confirmed; they observed that metallic sodium was liberated during the distillation. On the other hand, some cyanide was produced by heating the above-mentioned mixture in an electric furnace. It has been pointed out by other investigators that the construction of apparatus for the heating of mixtures of alkali carbonates and carbon presents serious mechanical difficulties. That is probably one of the reasons why similar processes suggested years ago were abandoned; the preparation of ferro-cyanides from alkali carbonates and animal residue is old, of course, and that iron serves as catalyst in such reactions was more or less recognised.

BIRMINGHAM ELECTRICITY SUPPLY.—On the report of the Electric Supply Committee, Mr. Burman, the chairman, moved that the offer of Lord Norton to sell to the corporation the Hams Hall estate for 37,500*l.* be accepted, and that the Finance Committee be instructed to apply to the Local Government Board for sanction to borrow 38,000*l.* to cover the purchase money. This was a proposal, he said, to purchase an estate of about 1,000 acres for a new electric power-house. The new station was not required immediately, but the committee were looking forward ten years and even more. The justification for the proposal was to be found in the continuous growth of the electric supply department. Eighteen years ago, when the corporation took over the supply, their first twelve months' trading produced a gross revenue of 55,000*l.* This year the gross revenue would closely approach 1,000,000*l.* Then, they sold just over 3,000,000 units of current; now they were selling 160,000,000 units, or more than 50 times as much. Since the outbreak of war output and revenue had more than doubled. From the beginning the committee had had constantly to extend the works. The Summer Lane station, which was not a small one, was fully developed in ten years. At the same rate of expansion, which might, however, be accelerated, the Nechells station, on which they were now engaged, would meet the city's requirements for fifteen years. With regard to coal, Birmingham was favourably situated, but as to water, no large river flowed near. Last year they burned 314,000 tons of coal at a cost of 298,000*l.* In the cooling towers at Summer Lane they had in daily circulation nearly 30,000,000 gallons of water, of which there was a small daily loss by evaporation. At the new permanent station at Nechells, when developed to its full capacity, it was estimated they would have 84,000,000 gallons in daily circulation. Along the western boundary of the Hams Hall estate there was an aqueduct through which flowed daily some 25,000,000 gallons of water. It was the effluent from the Minworth filter beds of the Drainage Board, and it ran to waste. No other such head of water, natural or artificial, was to be found within 20 miles of Birmingham, and it was the presence of this water which was the determining factor in the selection of the Hams Hall estate. The price was also believed to be a fair and reasonable one. The report was approved without discussion.

SCIENCE AND INDUSTRY IN RELATION TO NON-FERROUS METALS.*

(A CONTRIBUTION TO A GENERAL DISCUSSION.)

By WALTER ROSENHAIN, B.A., D.Sc., F.R.S.
(Vice-President).

So much has been said and written on the importance of science to industry that it may seem, at first night, superfluous to bring the subject up for general discussion, particularly as in doing so we are making a departure from the previous practice of this Institute. But the subject is of supreme importance at the present moment when it behoves us to put into practice the lessons which have been demonstrated to us—only too often in a painful manner—during the past four years of supreme trial. Among these lessons, the recognition of the importance of science may well be placed in the fore front. But the mere recognition of such a general principle is far from sufficient to secure the future of our industries, and it is the vital importance of securing the full and wise application of that principle in our national and industrial practice that justifies the present discussion.

Having heard and read much of what has been said and written on this subject, and knowing something, also, of the practical efforts in this direction which have been made both by the Government and by Industrial Associations, the writer feels far from satisfied that either party have as yet fully realised the situation, or that they have thoroughly understood and appreciated the conditions which appear to him to be essential to the attainment of the desired end—the mutual advancement of science and industry. For it must be realised at the outset that fruitful results on the larger scale can only follow if both science and industry are advanced together; the mere "exploitation" of science by industry is not possible and cannot lead to results, except in isolated and exceptional cases. In order to secure this desired result, however, it is not sufficient to accept as a general principle the "importance of science," nor even to spend large sums of money on so-called research. It is necessary for those guiding our industries to understand the nature and workings of science sufficiently to afford it full scope, for its activities and powers, while at the same time they must be ready, with skill and enterprise, to avail themselves of the results put before them, and to turn them to industrial utility and profit. What is needed is the right attitude of mind as well as a certain aptitude of purse.

Perhaps the greatest danger to the fruitful collaboration of science and industry, as the writer sees it, is that the practical man of industry may desire to exercise too great a guiding influence on the directions of scientific effort. It has been frequently suggested that "the practical man knows what he wants," and that consequently it is for science to provide it for him. While within certain narrow and well-defined limits this maxim may sometimes be true, yet is is no disparagement of the "practical man" to suggest that in reality—at all events in the wider sense of the words—he neither knows nor can possibly know "what he wants." He may know—as we all know—that he wants a better alloy for this or that specific purpose, a better and more efficient type of furnace, a more economical rolling-mill, and so forth; nor is there any doubt that to each and all of these the methods of science will help him, if used in the right way. But in the majority of cases, "research" directly aimed at solving such detailed problems becomes nothing better than systematic trial-and-error experimenting. This has its use and its well-earned place in any scheme of organised "science and industry," but it is neither the beginning nor the end of the application of science to industry.

For, if the practical man—or any man, for that matter—really knew "what was wanted," then all our progress would lie along foreseen lines. Yet the records of all our progress, both industrial and scientific, show the very reverse. What practical man would have said, at the time when Faraday began his work on the electromagnet, that he was in urgent need of a new and unknown force which should drive his machinery at a distance, light his factories, workshops, and streets, and perform the thousand and one miracles which we owe to the discovery of electromagnet induction by Faraday? What practical man, again, would have told us—before the early work of Perkin—that he demanded of science to show him how to make a thousand dyes and drugs out of coal tar? One might multiply the instances almost endlessly, going back, perhaps, as far as Columbus, who set out to find a sea route to India and discovered America. This last illustration, however, is perhaps the best, because it brings home the fact that all true scientific research—for whatever end it is conducted—is of the nature of exploration into an unknown region full of promise, and if we are wise we will shape our attitude towards it accordingly. Success, both for industry and for science, is to be achieved not by endeavouring to urge scientific discovery into predordained industrial channels, but to utilise the results of scientific discovery as they come, and to seek constantly to turn them to practical uses.

Another danger, and one closely related to that just discussed, lies in the idea—sometimes implied, although not formulated in so many words—that science is a finished whole lying ready to be used and adapted to industrial needs, or to be consulted at will, like an encyclopædia or a book of recipes. With the total lack of all scientific training which is still permissible in a man of "liberal education," it is not surprising that such astonishing misunderstandings of the nature of science should exist among men otherwise of more than average intelligence and capacity. But cases are known to the writer where otherwise intelligent manufacturers expected to have the whole resources of science brought to bear upon their industry, with a resultant immediate increase in their profits, by installing in some ill-ventilated and not over-clean room styled a "laboratory" a young and ill-paid chemist. The work and growth of this Institute are, of course, strong evidence that such cases would not be met with at the present time in the non-ferrous metals industries. But apart from absurd and extreme cases, there is still a tendency to expect too much for too little. It is true that there are, particularly among what may be impersonally described as the more backward industries, cases where the mere direct application of existing knowledge would work wonders by way of improvement. A case might be quoted, for example, in which a firm were called upon to supply a metal which had to meet a certain specification for which heat treatment was required. They failed to satisfy the requirements, and submitted a series of samples for each of which the temperature of treatment was stated to within 5 deg. C. Tests showed irregular results—and then, on inquiry, it was found that the temperatures had been "gauged by the eye of an experienced workman," and that the firm in question had never used a pyrometer. While the application of what may fairly be called elementary science to such cases is urgently necessary, it is to be hoped, in the first instance, that relatively few such still exist in the non-ferrous metals industries. The point to be borne in mind, however, is that the great joint effort of science and industry, which alone can place our technical industries in the forefront of the world's progress and achievements, will assuredly not find its objective in work of this kind; something altogether larger and deeper is required. It is this larger and deeper thing that science and industry together can, and must bring forth, upon which we must concentrate our attention, leaving it rather to the stress of competition to induce the laggard individuals in the industries to set their houses in order by the utilisation of what is well known and available to all at little cost.

If we accept this fundamental idea—that a great joint effort of science and industry is required to achieve the desired result of securing world-supremacy for our industries, what are the principles upon which our organisation of science for this purpose should be based? From this point of view, scientific activity in relation to industry may be divided into three great groups or classes, although these must necessarily overlap very considerably. These three great classes relate first to the advancement of science itself, then to the utilisation and adaptation of results to industrial uses, and finally, to the detailed application of scientific methods, results, and appliances to the control of industrial processes and products.

Fundamental to the whole edifice of fruitful collaboration of science and industry is the advancement of science itself. We are apt to speak, perhaps with undue boastfulness, of the achievements of science, and undoubtedly these have been great; but even then, we are but able to illuminate a little patch of knowledge in a dark universe full of unknown possibilities. The problem which science has attacked most successfully are probably the simplest among those which nature presents to us—or at least those which, by ignoring inconvenient complications, we are able to picture mentally as relatively simple. In fact, it is this very process of simplifying a problem by isolating its factors and investigating them one at a time which constitutes the most fundamental method of physical experimental science. As a result of this process we have succeeded in isolating a few of the more fundamental principles or formulæ by which we can correlate and describe the phenomena of nature, and these we term "laws of nature." But when we come face to face with the practical problems of life, whether in the works or elsewhere, the process of isolating and simplifying problems becomes very difficult. Practical problems have to be faced and solved as they stand, and although we find ourselves equipped with a certain amount of fundamental knowledge, there is scarcely a single practical problem which is presented to the most expert man of science which does not call insistently for "more knowledge" to allow of its satisfactory solution. Complete knowledge, and therefore the final and complete solution, is not to be looked for—but a little more real fundamental knowledge will make all the difference to the efficiency of the solution that is found. "More knowledge," then, is the real watchword for those who seek for real and lasting progress, whether in industry or science. But how is "more knowledge" to be obtained? Only by fostering and encouraging the highest forms of scientific research, conducted by the few men among us who are really capable of doing such work, without interference or "guidance" from outside. These greater minds work by methods of their own, and must be given every possible facility—material and financial—and all possible encouragement, both intellectual and national. It is not, it may be suggested, for any one industry to bear the burden of such pure scientific research—but since every industry is in the end dependent upon such work of pioneer discovery, each should bear its proper share in providing for such work. Nor should that share consist merely in financial contributions; the really capable scientific investigator is born, not made, and wherever found—be it in a works laboratory or in the workshop—should be regarded as "treasure trove," and carefully cultivated and safeguarded as a national asset. Where men show tastes and aptitudes in that direction, therefore, it is a matter of no small importance that they should be given an opportunity to develop their faculties, and thus to find their rightful place. Leaders of our industries are ever on the lookout for capable young men who will grow

* Paper read before the Institute of Metals, on Wednesday, March 26, 1919.

into valuable foremen, managers, or even directors—it is at least as important to remember that among their employees may be one who can advance science by discovery, and thus help to raise our place among the nations. Much might be hoped in this direction from a much wider spread of science as a subject for general education.

We have, then, as our first group or class, those who are engaged essentially on pure research or discovery. Many of these will have little knowledge of, and take small interest in, the practical possibilities of their discoveries; but there are some men who are capable of a second class of activity, which consists in the interpretation and adaptation of the results of pure research to practical uses. In some of its aspects this activity comes into the category usually called "invention." Some workers in pure research may, and do, find their inspiration and their subject-matter in practical questions; provided that they are left entirely free to pursue the paths to which their work leads them, their results may be all the more valuable because of the source of their interest. But such men—capable alike of conducting investigations in the highest branches of pure science and at the same time capable of dealing with practical problems—must as a rule, be few. What is needed for our proposed ideal organisation is, in fact, a group or class of interpreters and adapters, capable of following and understanding the progress of the highest and most abstruse research work, and able to see and appreciate its bearings and possibilities. Such men must be provided with large facilities—well-equipped laboratories and large installations of experimental plant in which they can work out to a practical purpose the consequences which flow from their constant study of the advances of pure science. Among them, or associated with them, must be men capable of carrying further any particular aspect of a purely scientific research which appears to promise developments of interest for the particular industry in question. A certain amount of purely scientific research will thus be carried out among the workers of this group also, but in this case as a secondary rather than a primary purpose.

Closely correlated with this group of "adapters and interpreters" are several other lines of scientific activity which are of very great importance, although secondary in value to the pursuit of pure science and the exploitation of its results. In this category may be placed the more systematic kinds of scientific work which are needed in order to furnish all the detailed knowledge which an industry requires. In regard to non-ferrous metals such questions as the systematic study of the constitution of alloy systems of increasing complexity may be mentioned in this connection—a line of study which would probably be correlated with an examination of as many as possible of the physical properties of the alloys in question. Work of this kind is of the greatest value and importance, since it furnishes many of the fundamental data upon which the use and treatment of alloys must be based in order to meet the increasing stringency of modern requirements. If carried on alone and continuously, systematic work of this kind is liable to become soul-killing for the worker, and he should therefore be encouraged to look for opportunities for work of a more exploratory or pioneering character. In the course of the systematic work he will meet with exceptional cases, unexpected peculiarities of properties or behaviour in an alloy, or some peculiar phenomenon in its preparation. These anomalies are as a rule the most potent keys to discovery, and the finder of such should be permitted and encouraged to follow up the clue which has presented itself to him, entirely irrespective of the apparent "usefulness" of what he is studying. Neither man of science nor practical man knows enough to tell whether the following of such a seeming by-path may not lead to results of far greater importance than the main issue to which the systematic research is directed.

The group of scientific activities which have been included in this second class which has just been discussed perhaps constitutes the most immediate concern of those connected with industry, and there can be no doubt that work of this kind must be carried out in close touch with the industry concerned. Men working at the adaptation and interpretation of scientific results for the benefit of the non-ferrous metals industry must be thoroughly well acquainted with the processes and needs of that industry, and must maintain close touch with it, so as to be fully aware of its progress and needs. On this ground it will probably be advisable to group with this second class of scientific activities a certain number of specific investigations suggested by or aimed at solving specific problems arising out of industrial practice. Workers dealing with such problems in a laboratory in which the "adapters and interpreters" are also at work would serve as a useful link with the everyday life of the industry. This link would be all the more useful because it would not be too close. Any attempt to direct the work of the "adapters and interpreters" too closely into lines which were supposed to lead towards the "requirements" of the industry would tend to sterilise their work—would constitute an effort to direct progress into pre-ordained channels, instead of allowing progress in the industry to follow the natural forward trend of growing scientific knowledge.

It has already been pointed out that among the "adapters," and among those carrying out systematic or specific inquiries or researches, some would tend to follow up paths of pure research opening up from their work. These would form a link with the pure research workers of our first class. On the other hand, others would find more congenial activities in working out the practical applications of the discoveries upon which they had worked. Such workers would find their main interests in the "experimental plant" attached to the laboratory, and might subsequently pass into the works or the works laboratory for the purpose of carrying on the scientific control of the new process which they had worked out on the experimental scale. In this way, the various classes or groups of workers would overlap and feed one another, producing a complete and harmonious system in which science would enrich the industrial soil upon which it flourised.

Finally, there is a third class or group of scientific workers for industry which is quite as essential to a complete and successful organisation as the other two. The business of this group or class is to carry scientific methods into the works themselves—not merely into the works laboratory. In the works themselves there is need for a large amount of scientific control—not only of raw materials, intermediate products, and finished output, but also of methods and appliances. This aspect of the subject is, perhaps, better recognised than either of the other two. All the larger works dealing with non-ferrous metals now possess laboratories, but frequently attention is devoted solely to the chemical analysis and mechanical testing of the metals produced, although the uses of the microscope and the pyrometer have now come to be widely recognised. But the mere establishment of a works laboratory carrying out routine testing, and even making efforts to carry out some research under difficult conditions, is not sufficient to meet the requirements of a satisfactory collaboration of science and industry, even in regard to this one aspect of the subject. What is needed is the introduction and maintenance of scientific method throughout the working processes. To give an indication of the class of activity contemplated, it may be asked how many of those engaged in rolling brass, for instance, are able to give a really satisfactory reason for the size of roll, reduction per pass, and speed of rotation of the rolls they employ? No doubt at some time in the history of those or some other works in the same district, some trials of various sizes and speeds, cambers and reductions were made, and the existing practice based upon them. But in how many cases are these the mere result of rule-of-thumb, based on no systematically-acquired knowledge, and therefore, in all probability, far from being the best and most economical? Similar instances might be quoted from nearly every branch of industrial practice. No doubt a great deal has been learnt and handed down as the result of "practical experience"—and no doubt a good deal of what is thus handed down is more or less true. But the consequence of these traditional processes is that our industry is clogged with much that is purely traditional and unnecessary—if not actively harmful. In many cases this state of affairs is not to be remedied so much by laboratory investigations or by scientific research as usually understood: what is needed is the steady and systematic application of scientific methods to actual works management and design. After all, the scientific method of obtaining data by carefully-thought-out experiments or trials is merely an accelerated and systematised way of obtaining the results of "experience." To apply these methods—and a case in which this has been done with brilliant success has recently come under the writer's notice—what is needed is the spread of scientific methods of management. Here the function of the second group of scientific activities, occasionally furnishing men primarily interested in the practical working of their processes, will serve as a valuable source of the right kind of material. The kind of man required may well be termed the "practical scientific" man, and provided our organisation is properly arranged, he should be readily forthcoming in sufficient numbers.

If this general outline of the nature of the various groups or classes of scientific workers required for the fruitful collaboration of science with industry be—for the sake of argument—accepted, the question arises by what practical means can such an organisation be set up and maintained? The answer must depend very largely upon the exact conditions prevailing in any given industry. Where there are single very large firms, it might be possible for one firm to provide for the entire organisation within its own borders. Thus, so far as the first group—workers in pure science—are concerned, it might endow one or more research professorships or maintain an entire research laboratory devoted to pure scientific research at a local university or at a great national centre. Provision might then be made for as close connection between the special research laboratories of such a firm and the university in question, by taking research students from the college into the firm's laboratories and, reciprocally, by sending some of the scientific staff of the firm to carry out pure science investigations arising out of their work in the college laboratories. For the second group of activities—for the "interpreters and adapters," systematic investigators, special inquiries &c.—the firm might well establish a great research laboratory equipped both on the purely laboratory side as on that of the experimental plant—on a large and ample scale. Finally, for works control and scientific management, provision could easily be made.

The scheme thus outlined is, it may be remarked, by no means Utopian in character; both in America and Germany schemes somewhat on these lines have been developed with very great success. On the other hand, there can be no doubt that adequately to carry out such a scheme would only be feasible for the very largest individual firms, and it is probably correct to say that there are very few industries in this country in which individual firms exist which are large enough to enter upon such a system. It is quite probable that in the non-ferrous metals industry no such individual firm exists. The alternative in such a case appears to be a combination of a number of firms into an association, with the object of jointly entering upon a systematic effort at the collaboration of science and industry. Further, in view of the large expenditure undoubtedly involved in any adequate scheme, and of the truly national importance of attaining a satisfactory result, financial aid from the State should reasonably be looked for. This State aid may, of course, take several different forms, each of which supplements the other. The most direct form of assistance would consist of direct grants in aid to the special Research Associations, and provided that such grants are not hampered by restrictions which—however desirable they may appear from the administrative point of view—serve to hamper the real work of the association—they should assist very materially in the development of their activities. Beyond this, however, the State undoubtedly owes other duties to science, and in fulfilling these in an adequate manner it will at the same time serve the cause of industry in the best possible way. This is by the provision of great centres of research and investigation operating on both the first and second group of scientific activities referred to above. We have first the provision of great universities and colleges with numerous and adequately paid and equipped research professorships, where the most capable men can devote their own time to pure research unhampered by teaching duties or by control of any kind within the financial limits set to them. If these were available, we should see growing up in all our great intellectual centres schools of research which would attract some of our ablest young men—some of whom would devote themselves permanently to research, while others, after a training in work of the highest class, would find their way into other branches of scientific activity. Beyond this suggested great expansion of the research activities of our universities and colleges the State may fairly be called upon to provide one or more great national laboratories dealing both with pure research and with the scientific activities of the second group referred to above. This national laboratory or laboratories would serve many useful purposes in the scheme of organised "science and industry" which has been outlined above. To a considerable extent it might serve as a general laboratory in which much of the work of the Research Associations could be carried out, and it would offer certain very considerable advantages for that purpose. Perhaps the greatest of these lies in the avoidance of a tendency towards undue specialisation, which must be regarded as a danger besetting any laboratory working under the control of an individual industry. A great national laboratory should be capable of commanding the services of leading scientific experts in all the main branches of scientific activity; consequently, while the electrical industries, for example, might establish a research laboratory of their own, with similar institutions for metals, iron and steel, cement, glass and other industries, there would be some difficulty in keeping these in touch with one another. In our own industry, for example, there is no doubt that workers in ferrous and in non-ferrous metals know far too little of each other's practices and difficulties. In a great central national laboratory investigations in all these subjects would be carried on side by side, and the workers engaged upon them would be in close contact—there would be constant interchange of ideas and very great mutual stimulus and benefit. Even within the relatively limited activities of the existing National Physical Laboratory, much benefit is derived by all researches and investigations from this cause. Such a laboratory could command the services of a greater number of experts of the highest class than could possibly be provided in a number of separate industrial research laboratories. In this connection it may be well to refer to a difficulty which is perhaps temporary, but is none the less of first-rate importance—that is, the very real shortage of capable scientific investigators available at the present time. This is not primarily a result of the war, but rather of the small amount of attraction which a scientific career has hitherto been able to exert on men of the most competent type. So long as the prizes to be gained by successful scientific activity are so much smaller than those held out by other professions, such as law and medicine, we shall continue to suffer from this shortage. But, whatever the cause, there can be no doubt that such a shortage does exist, and it follows that if numerous new research laboratories are set up in the near future they will be inadequately staffed—and inadequacy as to quality is even worse than in regard to quantity. This is a very real danger, and suggests the desirability of a certain amount of concentration in the efforts of the research activities in connection with various industries. A relatively small number of competent men working at a single central national laboratory can supervise and direct a large number of researches—in many cases, a single research will serve the purposes of several industries, or, rather, will furnish results which are capable of being utilised by several industries. It would seem, therefore, that there is good ground for asking the various new industrial Research Associations to support the National Physical Laboratory—a course in which they will be availing themselves of facilities provided by the State.

The writer has stated elsewhere his views and ideals in regard to the work and aims of the National Physical Laboratory ("Lecture to the West of Scotland Iron and Steel Institute," 1915), and there is all the less need to traverse the same ground again; he will therefore leave this aspect of the subject in expressing the hope that there may be the closest possible connection between the newly-formed Non-Ferrous Metals Research Association and the National Physical Laboratory. He must not, however, be regarded as suggesting that the scope of the work of such an association should be in any sense confined to the initiation and support of researches at any one Institution. The questions to be dealt with are so numerous and so important that there must be room for much research work at a number of existing Institutions. Laboratories of those colleges and universities which are equipped for metallurgical work will no doubt be utilised, while the question of the erection of special laboratories—and, more particularly, of expensive

experimental plant—will no doubt have to be faced sooner or later. It may, in fact, be suggested that one of the most important functions of any Research Association may be found to lie in the later stages of the second group of scientific activities outlined above. When the process of reducing the results of some research to industrial applicability has gone as far as it satisfactorily can, even in a great laboratory equipped with experimental plant, it may require to be taken in hand by a special staff under the direct control of the Research Association in order to be carried to the point of successful production in a specially large experimental or small production plant. The cost of commercialising a new process or material is often very large, and discoveries are apt to remain unused because individual firms do not care to face the cost. But a Research Association is in a different position; since it represents the interests of the whole industry, it need not fear that others may reap the benefit of expenditure incurred in development work of this kind, while the incidence of the actual cost is widely spread. It may therefore be hoped that such an association will be ready to display a degree of enterprise in the effort to utilise the results of research, which has sometimes been conspicuously lacking so long as we were dependent on the initiative of individual firms.

It is hoped that the above remarks may serve as a sufficient introduction for a discussion of the whole subject by the Institute. The writer has, unavoidably, looked at the whole question from the point of view of a scientific worker—but that point of view may surely claim a large share of consideration from those who wish to profit from the results of scientific labours.

SOCIETY OF GLASS TECHNOLOGY.

THE March meeting of the above society was held in the University (Mason College), Birmingham, on Wednesday, March 19. After the usual formal business, the following paper was read by Mr. B. J. Allen, "*The Preparation of Raw Materials for, and the Casting of, Glass Pots.*" The author dealt first of all with the deflocculation of clays, and showed how it could be accomplished by electrical treatment. He described a simple apparatus for testing clays to show their suitability under this electrical treatment. His experiments have proved that many common fireclays altogether unsuited in their ordinary state for the manufacture of refractories could, by the above treatment, be made to produce a large proportion of highly satisfactory material fit to meet the specification for high-grade work.

Mr. Allen dealt briefly with the manufacture of pots by the old method of building by hand, and dwelt briefly on the limitations of this method. It is most difficult for the pot maker to guarantee a perfectly united homogeneous pot. It is very essential that clay and the grog be in intimate contact in the finished pot, and this is ensured by the casting of the pot. He then went on to describe in detail the preparation of slip and subsequent casting of pots. He also described in detail different types of pots. The lecture was well illustrated by lantern slides and specimens, and the lecturer gave it as his opinion that research on all these matters should be carried out by the society.

During the morning, members, at the kind invitation of the directors in each case, had the opportunity of visiting: (*a*) Messrs. Icknield Glass Works (Oslers), Limited, Freeth-street, Birmingham; (*b*) Messrs. P. Branscomb, Glass (Bottle) Works, Adderley-street, Birmingham.

DEMOBILISED TRANSPORT MEN.—The National Council of the Commercial Motor Users' Association (Incorporated) has had under consideration steps to assist demobilised officers and men of the Army Transport who belong to its membership. Large numbers are known to be desirous to embark upon some branch of active work in conducting commercial motor haulage, goods or passenger, but are deterred for want of impartial advice. The National Council has therefore decided to provide for the services of a qualified and expert advisory engineer of standing, in order to assist in safeguarding these returning soldiers against the risk of participation in uncommercial or unsound enterprises. Inquiries should be addressed to Captain F. G. Bristow, General Secretary, Commercial Motor Users' Association, 83, Pall Mall, London, S.W. 1.

DELIVERIES TO BELGIUM, THE RHINE, ALSACE LORRAINE AND SWITZERLAND.—The Department of Overseas Trade (Development and Intelligence), 73, Basinghall-street, E.C. 2, state that arrangements have now been made which will enable goods to be despatched to Belgium, the left bank of the Rhine and Alsace Lorraine *via* Holland, without the production of N.O.T. certificates. Any exporters who desire to despatch goods by that route can do so provided the goods are consigned in transit and the bills of lading are made out to the Standard Bank of South Africa, Rotterdam, for account of the sub-consignee. Goods for Switzerland may also be forwarded *via* Holland, but in the case of such goods they must be consigned to the Standard Bank of South Africa, Rotterdam, for account of the S.S., for account of the actual consignee. His Majesty's Customs have been requested to allow goods for Switzerland to proceed *via* Holland if consigned as above, even though the licence may specify another route. The object of these arrangements is to enable goods to be exported to Holland in transit without the production of N.O.T. certificates, as the Standard Bank of South Africa, at Rotterdam, have undertaken to ensure that no goods consigned to them shall be detained in Holland, but shall be re-forwarded by them to their ultimate destination.

THE INSTITUTION OF ELECTRICAL ENGINEERS.

THE Council of the Institution of Electrical Engineers have decided to appoint a number of committees for the purpose of helping in the dissemination of information regarding recent progress in various branches of electrical engineering. The first of these to get to work is the committee dealing with wireless telegraphy. During the war, radiotelegraphy became so very important for military purposes that many new developments had to be kept as secret as possible; at the same time invention and discovery became very rapid. In consequence, there is a great mass of unpublished information which will become available for the general public at an early date. The Institution is going to offer special facilities through its new sectional committee for the publication and discussion of this new knowledge. Apart from the fact that knowledge grows by being circulated, it is especially essential to this country that wireless telegraphy should now be quickly transferred from the service of war to that of peace and that our manufacturers should all have as much information as possible placed early at their disposal. By starting this section for the organisation of meetings the Institution hopes to help the non-official public in the overtaking of four years of arrears in the study of wireless telegraphy.

Before the war the Wireless Society of London had come into being, and was doing excellent work on behalf of the amateur. This society, it is hoped, will resume its work in due course. Besides this there were at times efforts made to form a new special professional society for dealing with wireless telegraphy, and something resembling the Institute of Radio Engineers of America was projected. It has always been felt, however, that there are very real disadvantages in separating the men devoted to different branches of electrical engineering, and that there are advantages in keeping in touch even such extremes as the men who handle megawatts, and those who handle microwatts. In fact, there is a general tendency for societies with a community of interests to amalgamate, and thus if a special society were formed for radiotelegraphy it might only lead after a few years to a train of negotiation for absorbing it into the Institution of Electrical Engineers. The advantages offered by the policy now being initiated by the Institution are obvious; for on the one hand the Institution cannot but be strengthened if it attracts the whole body of wireless telegraph engineers into its corporate life, and on the other hand the Institution can give at once to matters affecting the interests of wireless telegraph engineers the weight and prestige of the whole body of electrical engineers generally.

LIMITS OF POWER TRANSMISSION BY ALTERNATING CURRENTS.—Some stir was caused among German electrical engineers when, in a meeting of the Elektrotechnische Verein, held at Berlin in the last days of November, 1918, M. von Dolivo-Dobrowolsky, the prominent advocate of three-phase currents of thirty years ago, pronounced in favour of transmission by direct currents. The first successful long-distance power transmission of 1891, 300 h.p., from Lauffen, on the Neckar, to Frankfurt-on-the-Main, a distance of nearly 110 miles, was effected with the aid of the three-phase machines of Dolivo-Dobrowolsky. Financially, the experiment, which was the chief feature of the Electrical Congress of Frankfurt, 1891, was not a success; but it did a great dealt to bring about a revolution in power transmission from direct currents over to phase currents. Now Dobrowolsky predicts another revolution, a return to direct currents, because conditions have altered, and phase currents are not suited for the modern problem—distribution of electricity over vast areas and to far distances from central power stations by subterranean cables. He dealt in general with the difficulties especially of the self-induction and capacity of phase currents in cables without recommending any particular system or devices. High-tension continuous-current distribution, notably on the Thury system, has of course, been urged all these years.

SWELLING OF SILICA WATER GLASS.—A peculiar case of "swelling" of silica was reported by K. Hebbeler in the *Chemiker Zeitung* last year (vol. xlii, pages 593 to 602). Though the case does not appear to have any direct practical bearing, it is not without interest. When 2 grammes of kieselgulor are shaken with water, the siliceous sediment will settle in the course of the day, and this sediment will take up, above 12 cub. cm., from 8 cub. cm. to 18 cub. cm. of the original 250 cub. cm. of water. The water is then poured off, and replaced by calcium hydroxide (milk of lime), the solution being renewed every day. In the course of a week or two the volume of the sediment increases very strikingly, up to 196 cub. cm. that is, more than ten times in one case observed. One might ascribe this swelling to the formation of calcium silicate, all the more so, because the hydroxide solution poured off contains less calcium than when poured on the kieselgulor; but a silicate is not formed. Nor is the swelling due to any increase in the size of the silica particles themselves. The phenomenon is apparently purely physical and due to the occlusion of calcium hydroxide within the porous silica; most of this lime can be washed out again by means of water containing a little carbonic acid. The same journal contains, on pages 589 and 582 also, an article by O. Maetz on the manufacture of water glass, sodium silicate, which is now generally made from Glauber salt (sodium sulphate, replacing the formerly-used carbonate), sand and coal; more coal is wanted with the sulphate, which is also more destructive to the furnace, but the salt is cheaper than the carbonate.

CATALOGUES.

Lubricants.—A catalogue dealing with lubricants in solid, grease and oil forms, comes from Sterns, Limited, Royal London House, Finsbury-square, E.C. 2. It contains useful information about the application of lubricants to various kinds of bearings.

Oil Engines.—Nya Aktiebolaget Atlas, Stockholm, send a copy of their catalogue of portable and stationary oil engines, in Swedish, and four sectional catalogues, in English, dealing with land and marine oil engines up to 550 nominal horse-power. All these are well produced, and show full details of construction.

Electric Lamps.—Lanterns, reflectors and all accessory fittings for workshop, yard and other commercial uses are shown in a new catalogue issued by the Wardle Engineering Company, Limited, 196, Deansgate, Manchester. Concentrated and dispersed light is provided for by different and special designs. Much practically useful information is added.

Chain Drives.—A pamphlet of 12 pages, entitled "Notes on the Selection of Chain Gear," has been issued by Messrs. Hans Renold, Limited, Didsbury, Manchester, to assist engineers in calculating and specifying the size and type of chain and sprockets required for known conditions. The data is given in tabular and graphical form for silent and bush roller chains.

Cottage Building.—The use of concrete blocks instead of bricks, and of cavity instead of solid walls is discussed in a special pamphlet issued by Messrs. Winget, Limited, 25, Victoria-street, S.W. 1, makers of machinery for mixing the concrete and casting the blocks. The system is already largely in use in this country, India and elsewhere for building cottages, hospitals, hangars and other buildings, the blocks being made on the site. Semi-dry concrete is recommended as strong enough and healthier.

Steels for Motor Cars and Aircraft.—Messrs. Edgar Allen and Co., Limited, Sheffield, have issued a special catalogue of steels for these and other purposes where both strength and lightness are required. The steel most suitable for every part is stated, and its qualities, working and heat treatment explained. The effects of heat treatment on nickel-chrome steel and chrome vanadium steel are shown by curves which will well repay careful study—they must be studied carefully, but they are a most excellently simple presentation of a complex subject. A decidedly instructive catalogue.

Capstan Lathes.—The capstan and turret lathe is making room for itself, notwithstanding the single tool lathes on one side and the "automatics" on the other. A bound catalogue of over 200 pages quarto, well filled with illustrations and text, from Messrs. H. W. Ward and Co., Limited, Birmingham, is strongly suggestive of a flourishing branch of engineering. Not only are these lathes made in many sizes, and in great variety from simple to complex, but the special tools and attachments are so varied and numerous that it is evident that the type has an increasing hold on an extremely varied class of work. Both lathes and special fittings show a developed form of design that belongs only to things largely used and with an enlarging future before them. Capstan lathes are made in 13 standard sizes, from 4 in. to 8-in. centres, and combination turret lathes in 10-in. and 12½-in. centre sizes. There are various modifications for chuck and bar work and for plain and geared headstocks. The feeds and speeds are numerous and all the details carefully worked out. The general form is shapely and very strong, capable of high-speed work. The catalogue in itself is a proof of the powerful hold on machine-tool making which the engineers of this country have secured. The prompt issue of such a catalogue so soon after the stress of forced production for war work is also some guarantee that British machine-tool makers do not intend to lose their grip on either home or foreign trade.

Army Motor Vehicles.—A review of work done for the army from 1899 to 1918 forms an interesting subject for a special catalogue issued by Messrs. John I. Thornycroft and Co., Limited, Southampton and Basingstoke. It is a creditable record, told without boasting and containing much instructive discussion. The first wagon, a steam-engined one, was actually sold in 1899 to the War Office for service with the Royal Engineers. Although it was an unquestioned success the War Office continued to borrow other wagons built by the same firm for two years, and at last gave an order for 10 wagons. The War Office then opened a public competition amongst motor wagon makers for a 500*l.* prize, and Messrs. Thornycroft entered, and secured the prize against ten other competitors. We recall these facts to remind the public that the War Office has a record for caution and economy which it may one day revive in the "public interest." These were the days when the hard and speculative work of founding our present pre-eminence in mechanical road transport was being done by engineering firms under conditions which bar the least suspicion of State generosity. Improvements and inventions followed year by year, the main support coming from commercial men. The elaborately economical subsidy scheme of the War Office was practically empty of results on the outbreak of the great war, and it was only by impressing mechanical transport outside the scheme that a show of efficiency could be made. This and much more is dryly related in this record. The booklet is worth reading and preserving. It shows, all the more forcibly for not being written with that intention, that the country owes some small debt of gratitude to the private enterprise of both builders and buyers of commercial vehicles.

H.M. SEAPLANE-CARRYING SHIP "ARGUS."

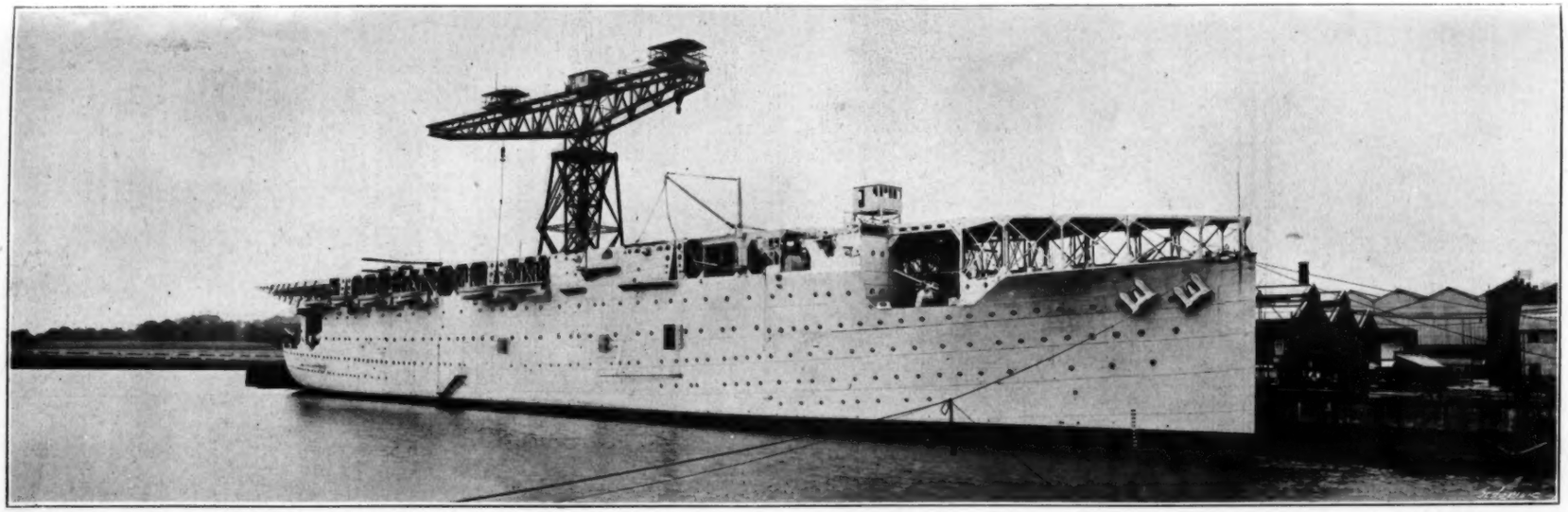


FIG. 4. GENERAL VIEW OF SHIP BEING COMPLETED.

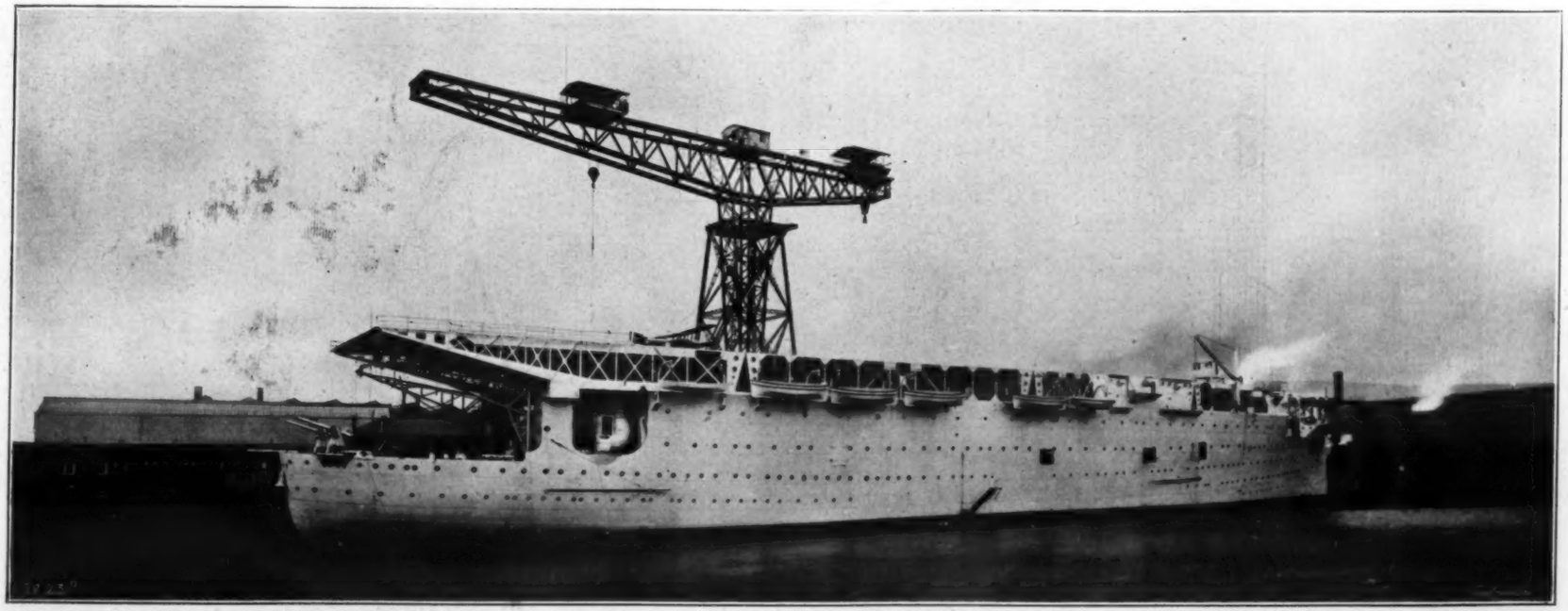


FIG. 5. VIEW SHOWING OVERHANG OF FLYING DECK WITH EXHAUST GAS FANS, CRANES, AND GUNS UNDER IT.

(*To face page* 402.)

H.M. SEAPLANE-CARRYING SHIP "ARGUS."

CONSTRUCTED BY MESSRS. WILLIAM BEARDMORE AND CO., LTD., NAVAL CONSTRUCTION WORKS, DALMUIR.

(*For Description, see Page* 400.)

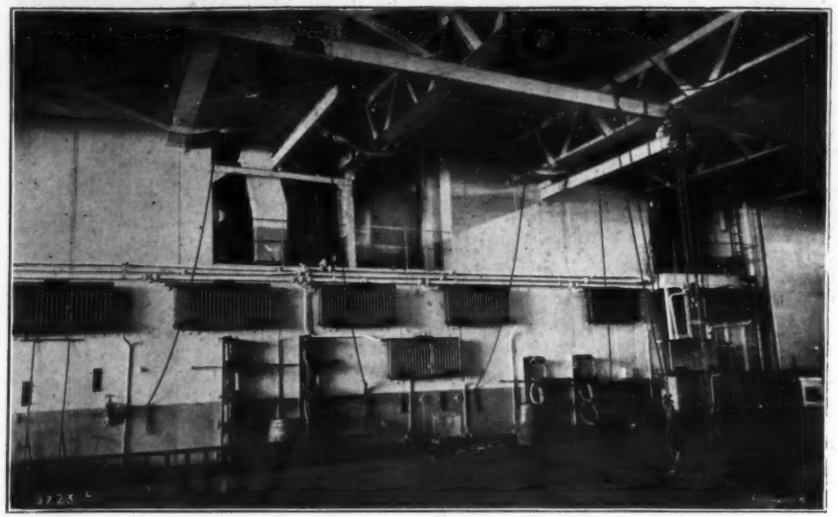


FIG. 6. INTERIOR WALL OF HANGAR, WITH RADIATORS, TORPEDO RACKS, &C.

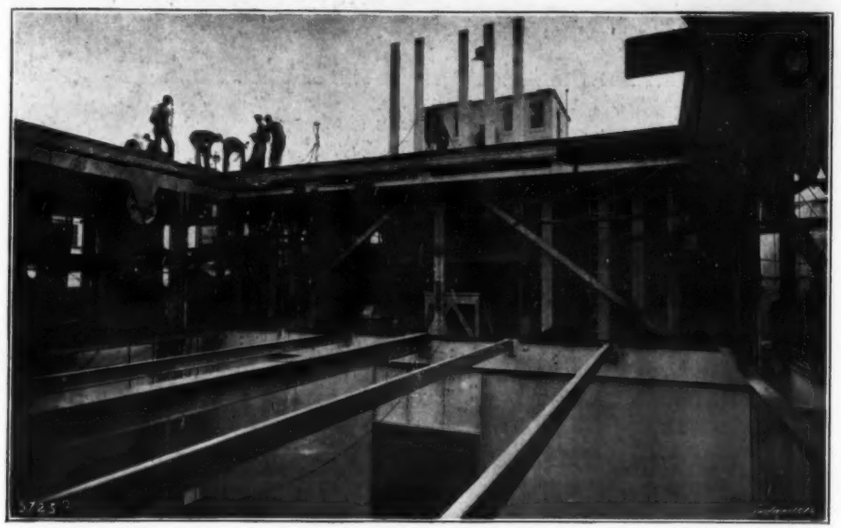


FIG. 8. WELL THROUGH WHICH AEROPLANES ARE RAISED FROM HANGAR TO FLYING DECK.

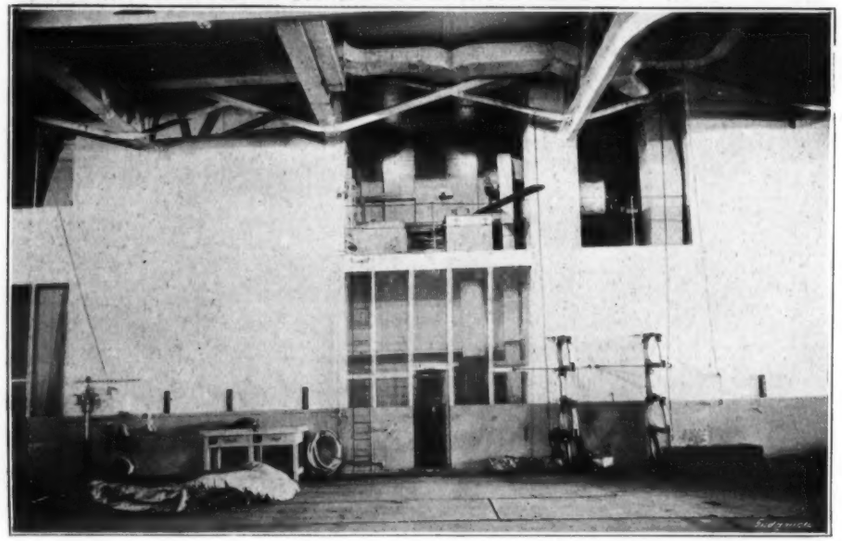


FIG. 7. STORE-ROOM AND VENTILATING UNIT IN HANGAR.

FIG. 9. TEST-HOUSE FOR AEROPLANE ENGINES AND PROPELLERS.

H.M. SEAPLANE-CARRYING SHIP "ARGUS."

CONSTRUCTED BY MESSRS. WILLIAM BEARDMORE AND CO., LTD., NAVAL CONSTRUCTION WORKS, DALMUIR.

(*For Description, see Page* 400.)

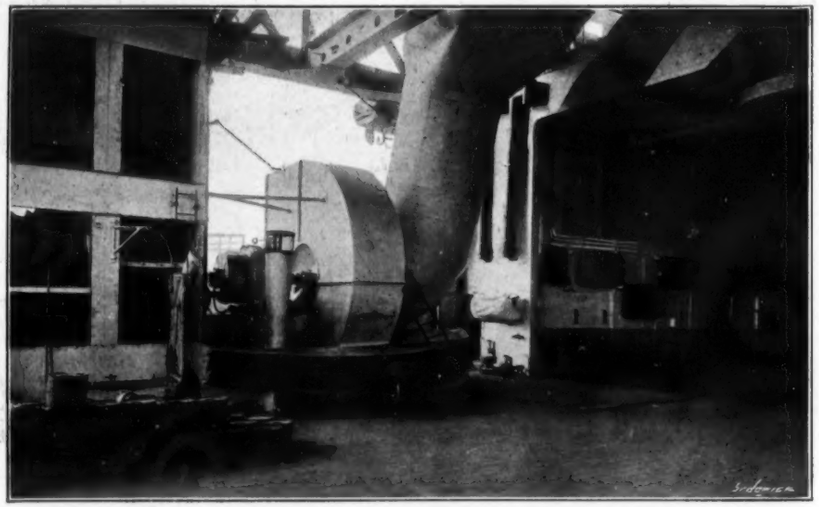


FIG. 10. FAN FOR HORIZONTAL FUNNEL.

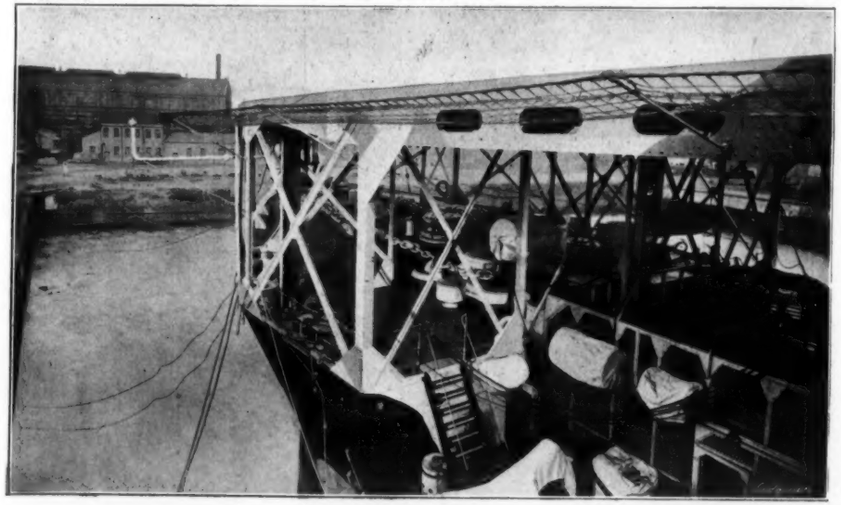


FIG. 11. PORT SIDE OF FORECASTLE, SHOWING SAFETY-NET, &c.

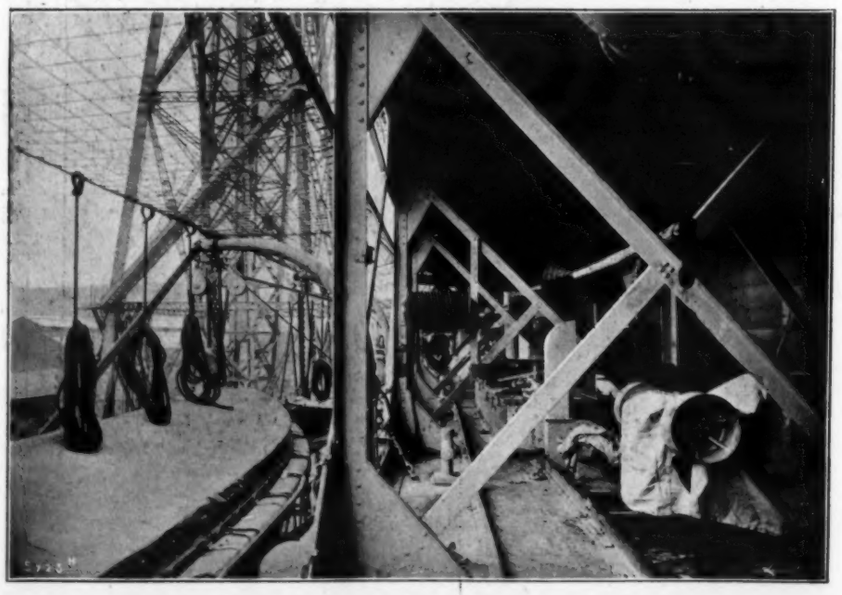


FIG. 12. BOAT STOWAGE AND SAFETY NETTING.

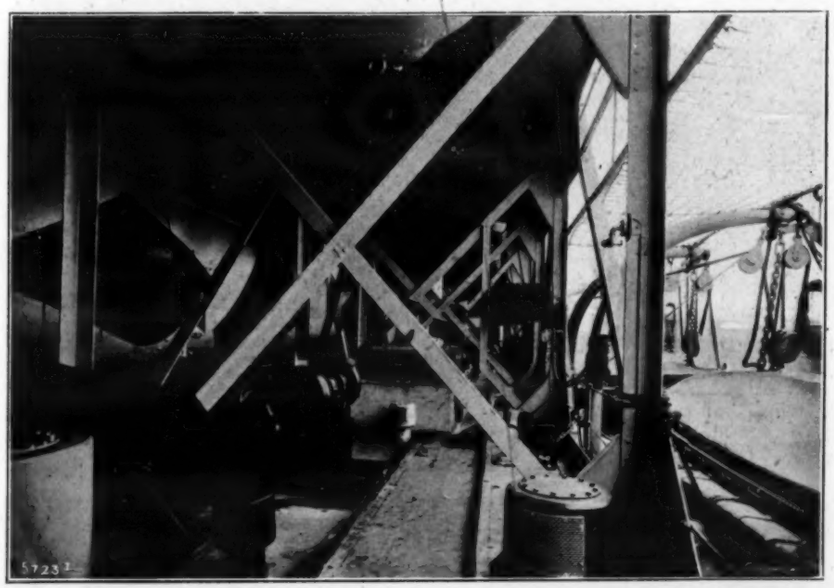


FIG. 13. VIEW SHOWING STRUCTURE SUPPORTING FLYING BRIDGE AND "CAMOUFLAGED" HORIZONTAL SMOKE DUCT.

H.M. SEAPLANE-CARRYING SHIP "ARGUS."

CONSTRUCTED BY MESSRS. WILLIAM BEARDMORE AND CO., LTD., NAVAL CONSTRUCTION WORKS, DALMUIR.

(*For Description, see Page* 400.)

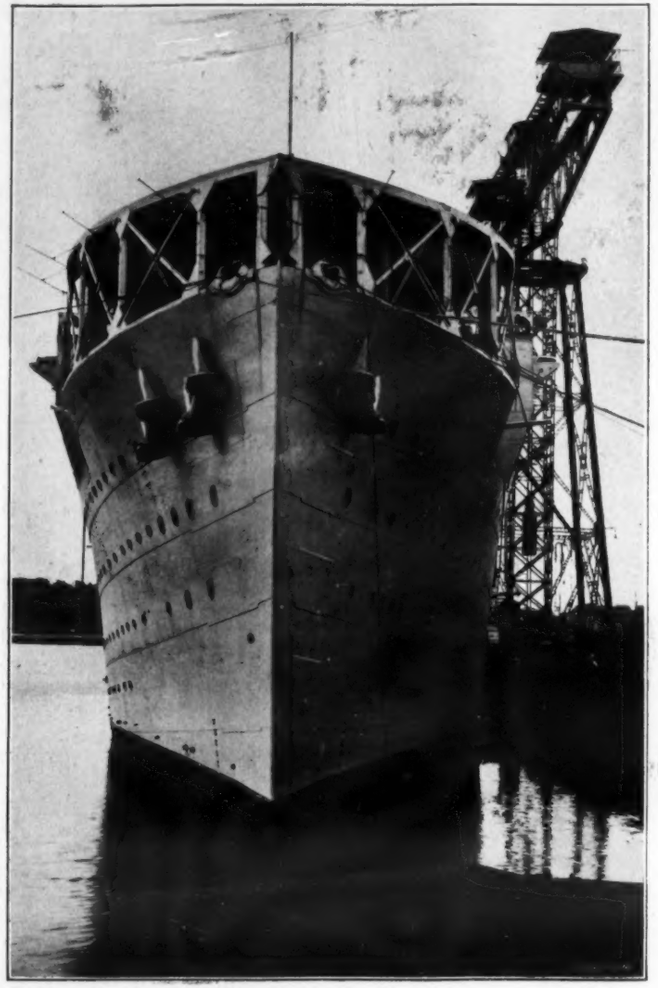


FIG. 14. BOW VIEW.

FIG. 15. STERN VIEW, SHOWING OVERHANG OF FLYING DECK, CRANES, AND GUNS.